(Part 4 of 5)

ALARA Training for Technical Support Personnel

Appendices

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APPENDIX A - APPLICATION OF ALARA TO FACILITY SYSTEM DESIGN

I. AIRBORNE RADIOACTIVITY AND HVAC SYSTEM CONSIDERATIONS

Ventilation systems deserve separate ALARA considerations because of the possibility of increased doses due to internal uptake of airborne and surface contamination. Routinely requiring workers to wear respiratory devices is not the preferred solution to reducing internal deposition of airborne radioactive materials.

The facility ventilation system(s) are a major means for controlling airborne radioactivity levels in occupied areas under both normal and abnormal conditions.

A. Essential Features.

Ventilation systems have two tasks: to direct airborne radioactivity away from personnel and to provide an adequate method to capture any airborne radioactive materials that are accidentally released. To attain these objectives, ventilation systems usually incorporate two essential features:

1. Appropriate differential pressure (DP) between ventilated areas and outside areas, and

2. High-Efficiency Particulate Air (HEPA) filtration.

B. Area-Specific Requirements.

Similar areas do not always require identical ventilation characteristics, especially differential pressure and filtration. Ventilation design criteria need a measure of flexibility since conditions may change as work changes and since local or portable ventilation may be effective at reducing local airborne radioactivity levels significantly.

C. Eliminate/Reduce Airborne Sources.

To ensure control of airborne radioactivity, design for the following as appropriate:

1. Properly seal and pressurize equipment and ducts with continuously welded seams and flange gaskets.

2. Leak-test HVAC equipment after installation and repair.

3. Select filters appropriate to the operation and radionuclides present (e.g., charcoal filters are good for iodine, but they don't last as long if they get loaded with nonradioactive particulates and dust; you may also need a prefilter for dust and/or a HEPA filter for particulates).

4. Provide differential pressure detectors across filters to monitor dust loading.

5. Avoid open-topped tanks or tanks with vent lines lower than tank overflow lines.

6. Generally avoid hard-piping tank vents directly to ducts if the tank may become pressurized.

7. Use good contamination control practice in designing for such tasks as filter changeout, wet layup of equipment, and machining contaminated parts.

8. Use water for backflushing and unplugging in preference to compressed gases.

9. Properly place and seal penetrations, gratings, openings, etc., which are open to areas of potential airborne radioactive materials.

10. Specify sealed bearing motors with the motor mounted external to the exhaust.

11. Provide intake air filters to minimize exhaust filter loading and dust accumulation in radiological areas.

12. Provide drains and/or dryers and/or moisture separators upstream of filters and charcoal beds.

13. Provide auxiliary or temporary ventilation systems for sampling stations used to sample highly radioactive fluids (e.g., reactor primary coolant) and for repair of equipment that when opened, has a potential for airborne releases. (Consider both temporary ductwork attached to existing systems and independent, portable HEPA-filtered ventilation systems.)

D. Air Flow.

A system of differential pressure should be used to direct the flow of any airborne radioactive material that escapes containment.

1. Room air may be recirculated if adequate filtration and monitoring are provided.

2. Direct air flow from areas with no or less potential contamination to areas with greater potential for contamination.

3. Primary confinement shall always have the least pressure in a facility (relative to the outside atmosphere).

4. A gradient should be established, on a facility and room basis, so that the lowest pressure and exhaust collection points are located in areas with potentially dispersible material.

5. Ducts carrying potentially contaminated air should be at a negative pressure when passing through a clean area.

6. Locate ventilation supply points above the worker or work area and away from the sources of contamination, or otherwise place as appropriate for the work activity (e.g., for work tables, gloveboxes, and hoods).

7. Avoid drawing contaminated air across walkways, doorways, entrances, work areas, and, especially, breathing zones.

8. Locate ventilation exhausts near the floor and away from entrances or openings to clean areas.

9. Locate ventilation fans as close as possible to the discharge, downstream of filters so as to avoid contaminating the fans and pressurizing the filters.
10. Exhaust through a filtration system from areas with greatest potential for contamination.

11. Minimize the number of elbows in ventilation ducts to reduce the plateout of radioactivity and to reduce flow losses. Alternatively, consider flow straighteners.

12. Size ducts and fans to have high enough flow rates to reduce plateout.

13. Select smooth materials or consider coating inner surfaces to reduce plateout.

14. Ensure that the opening of doors and removal of shield plugs does not disrupt proper air flow.

15. Provide connections to attach temporary ventilation systems where additional ventilation flow may be needed.

16. Design ventilation so as to minimize the use of respirators.

17. Use airlocks where appropriate.

E. Filtration Systems.

1. Select proper type, size, and quantity of air filtration devices.

2. Locate filters as close to the source as possible and upstream of any fans to reduce contamination buildup in ductwork and fans.

3. Provide roughing filters upstream of HEPAs, and HEPAs upstream of charcoal filters.

4. Provide flushing ports and drains for decontamination of filter housings and ventilation ducts.

5. Place filters for highly contaminated ventilation systems in shielded housings and locate filter banks in low-occupancy areas.

6. Design filter housings and filters so that filters can be removed remotely or quickly in the event of an incident.

F. Maintenance.

1. Design ventilation systems for ease of maintenance, inspections, testing, and operations.

2. Locate ventilation motors in low-dose-rate areas whenever possible.

3. The proper design of the ventilation system permits filters to be changed easily and with a minimum potential for the release of radioactivity and worker exposure.

4. The design shall provide the capability for in-place testing of the filtration system.

G. Monitoring.

1. All airborne and potentially airborne radioactivity areas shall be vented to a monitored release point.

2. The design should allow for continuous particulate sampling before the first testable stage and after the last stage, to provide direct evidence of filter performance.

3. Areas with a high potential for airborne radioactivity may require sampling between intermediate stages to verify the performance of each stage.

H. Emergencies.

1. Key ventilation systems in a radiological facility must be provided with emergency power to assure continued operation if normal power is lost.

2. Ensure adequate air flow throughout the area to provide quick cleanup of air during spills or leaks.

II. CONTAINMENT CONSIDERATIONS

A. Containment.

A containment is an area enclosed by a set of barriers. These can be passive barriers, like walls, or active barriers, like valves and ventilation flow.

1. The primary containment is the barrier or set of barriers most intimately in contact with the radioactivity.

2. The secondary containment encloses the primary and receives and handles any leakage from it.

3. A tertiary containment may also need to be provided.

One constraint on defining these is that it usually must not be possible for a single failure to compromise two containments at once (e.g., a primary and its secondary).

B. Primary Containment.

Containment is a way of thinking about a system configuration at a given time or in a given mode of operation, as well as having a physical meaning. For example, for a tank containing radioactive liquid, the tank itself is the primary containment, together with its intake and outlet piping up to the nearest isolation valves. When these valves are open, the primary containment extends to the next valve and so on. Also, a tank farther along may be a separate primary containment but can be considered, while the valves between it and the first tank are open, to be an extension of the first tank and, therefore, part of a single primary containment.

C. Secondary Containment.

The room(s) or vault enclosing the tank and piping are the secondary containment and should be so designed; the outer wall of a double-walled tank may be the secondary. The building itself may be the tertiary containment.

D. Gloveboxes.

Gloveboxes and other handling enclosures are primary containments when radioactivity in them is not completely enclosed or is enclosed in containers that cannot be assumed to be well sealed. Gloveboxes are secondary containments when the radioactivity is actually contained in a piping system, vessel, instrument, etc., inside the box. In the latter case, the room may be designed as the tertiary containment.

E. Primary Containment Penetrations.

Primary containment penetrations must be carefully laid out and minimized in number and size. They should be carefully sealed with regard to radiation streaming, air-flow control, fire protection, and flooding as applicable. Permeation of these seals should be considered. Transfer ports for passing items in and out should, in general, be airlocks or mini-airlocks, with purging capabilities.

F. Isolation Systems.

A principle of good confinement is good isolation; systems with widely differing levels of actual or potential radioactivity content should be isolated from one another by check valves or

other reverse-flow control devices. Pressure relief devices should be required, and leak detection devices should be provided as appropriate to the process.

G. Check Valves.

Check valves on tritium systems leak when closed and don't provide good confinement.

Because check valves have problems, they are often used in pairs. Their good points cause them to be extensively used, but they must be used wisely.

III. MECHANICAL SYSTEMS CONSIDERATIONS

This section dicusses six areas: piping, valves, pumps, filtration, tanks, and heat exchanger systems.

A. Piping and Tubing.

The following guidance should be applied in piping and tubing design.

1. Eliminate/Reduce Radiation Sources

   a. Route piping to minimize the length and number of pipe fittings and bends.

   b. Tee branch piping above the main flow piping or slope the teed branch upwards.

   c. Design piping to avoid dead legs and minimize tees.

   d. Provide a continuous slope on the piping to prevent backflow and settling of crud.

   e. Provide smooth surfaces to avoid crud traps and facilitate decontamination and flushing.

   f. Use materials with low nickel and cobalt content for reactor facilities or other facilities where neutron activation may occur.

   g. Route piping carrying highly radioactive fluids away from equipment requiring frequent maintenance.

2. Eliminate/Reduce Contamination Sources
   a. Segregate radioactive and nonradioactive piping.

   b. Provide adequate controls to prevent and/or detect cross-contamination of clean nonradioactive systems.

   c. Plumb pipe and leakage to floor drains and vents to ventilation ducting, where possible. But beware of pressurization that may send liquid or solid materials out of vents.

   d. Select piping and components that will maintain containment over the environmental qualification range to prevent release of radioactivity to the offsite environment.

   e. Avoid the field routing of piping that transports radioactive materials.

3. Maintenance
   a. Select low-dose-rate areas for installation whenever possible.

   b. Provide adequate vents and drains to allow for system testing, maintenance, and operation.

   c. Use consumable inserts for welding in lieu of backing rings for pipes carrying radioactive materials.

   d. Use butt welds rather than socket welds for pipes $\geq$1.5 inches. If a choice of welds is given in the welding specifications and if it is for a highly radioactive system, use a butt weld.

   e. Specify pipe bends of at least five pipe diameters in radius for the transfer of resin and sludge.

   f. Provide remote methods to unclog drain lines.

   g. Specify removable pipe insulation in areas where welds require in-service inspection.

h. Provide connections on piping and components to allow flushing, hydrolazing, or chemical decontamination on piping that contains resins, sludge, or highly radioactive fluids.

B. Valves.

Since operation and maintenance of valves are two of the major contributors to workers' dose, the design engineer should apply the following guidance:

1. Eliminate/Reduce Radiation Sources
   a. Install valves with stems in the upright position to minimize crud buildup.

   b. Select valves with internal surfaces and configurations that minimize crud buildup.

   c. Use materials with low nickel and cobalt content for reactor facilities or other facilities where neutron activation may occur.

   d. Provide steps in installation procedures to control stellite filings that are in valve internals (e.g., dams and/or vacuuming after grinding for reactor facilities or other facilities in which neutron activation may occur).

2. Eliminate/Reduce Contamination Sources
   a. Provide packing and seals that result in minimal contamination leakage and maximum reliability.

   b. Consider packless valves or those using live-loaded packing; valves above 2.5 inches should generally have double packing and a lantern ring.

   c. Locate valves away from low points in piping.

   d. Provide check valves to prevent radioactive fluid backup.

   e. Provide catch pans, floor and equipment drains, or curbing under valves that have a significant potential for leakage.

f. Separate valves carrying highly radioactive fluids from associated equipment and components.

h. Consider future decontamination when providing isolation valves for fluid systems.

3. Maintenance

a. Select valve materials that are compatible with contact materials.

b. Locate valves in low-dose-rate areas whenever possible.

c. Provide remote operators or reach rods for valves located in areas of elevated dose rates.

d. Locate valves in an area with adequate work space to provide easy maintenance, inspection, and operation.

e. Consider maintenance requirements on valves, operators, and reach rods (e.g., select those that are easily removed).

f. Generally provide flanged connections on valves that may require removal from the radiation areas (e.g., pressure relief or isolation valves) however, welded connections may be preferable in some cases.

g. Provide rigging and lifting points for heavy valves requiring removal for repair or inspection.

C. Pumps.

Pump design should include the following considerations:

1. Eliminate/Reduce Radiation and Contamination Sources

a. Provide a mechanism to flush seals on pumps carrying highly radioactive fluids.

b. Install catch pans or curbing around pumps that transport radioactive fluids and have a significant potential for leakage.

c. Provide drain connections on pump casings as well as smooth surfaces on impellers.

2. Maintenance
   a. Consider maintenance requirements on pumps, such as access and pull space for the motor shaft.

   b. Provide rigging and lifting points for heavy pump parts requiring removal for repair or inspection.

   c. Provide flange connections to facilitate removal of pumps located in areas of elevated dose rates to facilitate removal.

   d. Select pumps with mechanical rather than packing seals (canned-rotor pumps or magnetic-driven pumps).

D . Filtration.

Maintenance, inspection, and operational requirements for filtration/cleanup systems as well as shielding and isolation of highly radioactive systems must be considered.

1. Eliminate/Reduce Radiation Sources
   a. Provide filters upstream of deep-bed demineralizers to extend resin life and thus reduce radioactive waste volume.

   b. Provide strainers downstream of filters and demineralizers to entrain stray fines.

   c. Lay out demineralizers and resin storage components to assist resin flow and minimize piping (straight runs of piping with a minimal number of elbows).

   d. Provide filters and strainers that are back-flushable.

   e. Provide back-flushing capabilities sufficient to relieve plugged lines in resin slurry piping.

2. Eliminate/Reduce Contamination Sources
   a. Provide containment or ventilation to prevent spread of contamination during filter, strainer, and resin changes.

b. Provide screens, filters, or other catch devices over resin or sludge overflows and vents.

3. Dose Rate

a. Isolate or shield filtration systems that contain high radioactivity.

b. Locate filtration systems in low-occupancy and low-traffic areas.

4. Maintenance

a. Ensure that filters, strainers, evaporators, ion exchangers and routinely serviced items are compatible with existing equipment.

b. Ensure that filters, strainers, and evaporator tubes are easily removable and adequate space is provided.

c. Provide space for pallets to support temporary decontamination equipment that chemically cleans the system.

d. Provide remote methods for draining filter housings on systems processing offgas and radioactive water.

e. Provide remote and/or shielded methods for replacement of hot filters, strainers, and resins.

f. Provide flush connections that will facilitate high-velocity chemical flushes.

E. Tanks, Sumps, and Floor and Equipment Drains

1. Radioactive Material Handling Equipment

Choose radioactive material handling equipment carefully. Consider decontamination and eventual decommissioning. Apply the following design guidance.

a. Never undersize a tank used for holding radioactive material.

b. Select tanks with sloped or dished bottoms to facilitate flow/draining and to eliminate corners as potential low-flow areas where crud may accumulate.

c. Install top mixers, spargers, or spray systems as appropriate to mix the contents for transfer and representative sampling, and for decontamination prior to inspection or maintenance.

d. Ensure overflow lines are lower than the tank's vent.

e. Provide screens or strainers on tank vents and overflow for tanks containing resin or sludges.

f. Provide a slope from tank, drain, and sump bottom to outlet.

g. Provide curbing or other containment to restrict spread of leakage.

h. Locate radioactive material tanks and sumps in low-occupancy and low-traffic areas or shield to reduce personnel dose.

i. Locate tanks containing high radioactivity in shielded tank farms or cubicles.

2. Transfer Systems.

Prevent plugging in transfer systems:

a. Avoid long vertical runs ending in a turn to the horizontal, which may lead to plugging.

b. Reduce crud deposition by using pipes with at least 1-1/2 inch diameter, long bend radii, no right-angle bends, and sloping runs.

c. Choose full-ported valves, especially when the stream has a high-solids content.

d. Provide turbulent flow to maintain homogeneity and keep solids in suspension.

e. Choose full-ported valves when the fluid has a high solids content.

f. Consider automation of valve operation so that flow does not stop after a backwash or precoat.

g. Provide a "recirc" line to ensure good mixing before transfer.

h. Interior surfaces should be smooth and free of pockets to facilitate transfer and decontamination.

i. When transporting liquid radioactive waste by pipes, the pipe route should be isolated from uncontrolled areas.

j. Locate transfer lines in low-occupancy and low-traffic areas.

3. Maintenance/Decontamination

a. Provide adequate space for maintenance and repair of tank support equipment (e.g., pumps, agitators, gear boxes, etc.).

b. Select preferred cleaning methods. Hydrolazing is preferred to air blowout, which is preferred to rodding out. Screens or filters should be provided when using air blowout. Stringent contamination control measures should be used during rodding out.

c. Avoid lap joints and backing rings on welds.

F. Heat Exchangers, Moisture Separators, and Heaters.

Modifications or replacement of heat exchangers carrying radioactive fluids should consider the following:

1. Eliminate/Reduce Radiation and Contamination Sources

a. Provide drains at low points to facilitate flushing and cleaning.

b. Design vessels to reduce crud traps in those areas that require access during inspection and cleaning.

c. Select the proper material for the operating environment to minimize corrosion (e.g., titanium tubes for brackish water).

d. Orient heat exchangers in the vertical position, where feasible, to reduce deposition along the length of it.

e. Maintain radioactive fluids at lower pressures to ensure that leakage would be from the nonradioactive side into the radioactive side.

f. Provide curbing and drains to contain radioactive fluids during repair and cleaning.

2. Dose Rate

a. Pump fluids with the higher concentration of radioactivity inside the tubes to utilize the water in the shell as shielding.

b. Place heat exchangers that are expected to be highly radioactive inside shielded cubicles.

c. Provide adequate space to allow for removal and cleaning of the tubes and shell.

IV. ELECTRICAL POWER SYSTEM CONSIDERATION

The ALARA design considerations that follow are geared toward the power systems engineering discipline:

A. Routing/Location

1. Perform walkdowns or utilize photographs in low-dose-rate and low-interference areas to aid in locating conduit runs.

2. Route cable and conduit in low-dose areas.

3. Evaluate routing of electrical cabling through potentially contaminated areas in light of installation doses and accessibility requirements.

4. Locate breaker boxes, power control centers, and electrical cabinets in low-dose rate areas.

5. Physically separate local control and alarm stations from associated electrical equipment located in areas of elevated-dose rates.

B. Maintenance

1. Select long-life bulbs to decrease maintenance time in radiation and contamination areas.

2. Select electrical equipment with features that minimize inspection, calibration, testing, and preventative maintenance (e.g., quick disconnects).

3. Select high-quality electrical equipment with proven reliability records and low maintenance requirements.

4. Provide external access for fault location determination capability for those electrical systems that are difficult to inspect or troubleshoot.

5. Prefabricate conduit, supports, brackets, cable trays, junction boxes, and other electrical components to be installed in areas of elevated-dose rates.

6. Provide sufficient electrical outlets for air-sampling devices as well as for electrically operated maintenance tools, welding machines, and temporary power distribution boxes.

7. Provide adequate lighting as well as provisions for supplemental temporary lighting.

8. Ensure that the conduit and electrical equipment do not interfere with the maintenance or operations of nearby equipment.

V. SAMPLING, MONITORING, AND INSTRUMENTATION

A. Sampling.

It is important that the sample is representative of the material sampled with respect to location, physical state, and chemical composition.

Therefore, avoid having the sample deposit inside sample lines and equipment because it and subsequent samples might then be unrepresentative. The design engineer should apply the following guidelines to ensure representative sampling.

1. Follow the guidelines for reduction of crud deposition, especially considering the reactivity of the line material with the sample. For example, plastic piping may be best in many

cases because of low-chemical reactivity but may not be suitable for airborne particulates due to static charge buildup.

2. Provide sample lines that have few bends. Any necessary bends should have a large radius and be able to be isolated and flushed.

3. Provide a strong and continuous purge of sample lines in high-radioactivity systems.

4. Consider very carefully the proper flow velocity in the system, given the physical and chemical characteristics of the stream.

5. In gaseous systems, ensure continuous flow or well-tracked flow (consider flow meters, totalizers, constant-flow regulators, and recorders).

B. Sampling Station

The following design criteria is applicable to radioactive material handling areas.

1. Make sure any ventilation hoods have a face velocity of 100-150 linear feet per minute with the hood window in its full open position.

2. Direct ventilation hood exhaust to the facility vent upstream of the filters.

3. Route any sink drains in sampling or radioactive material handling areas to radioactive waste or retention tanks. Sinks should be free of any potential crud traps.

4. Construct or coat sinks and surfaces of sampling areas with materials that are easily decontaminated.

5. Separte or shield sampling stations from other radioactive components.

6. Provide adequate shielding or separation for high dose rate activities.

7. Minimize potential for cross-contamination of non-radioactive systems.

C. Monitoring.

Sufficient and carefully chosen radiation and air monitors should be provided to cover all areas where there is a potential for dose rates or airborne concentrations to exceed the limits of the respective areas. The design engineer should apply the following guidelines for selection and location of monitors.

1. Make sure that there are no obstructions or blocking of any monitor.

2. Provide methods to perform remote sampling and monitoring for airborne radioactivity, where appropriate.

3. Locate process and effluent monitors to provide enough detection lead time so as to divert or isolate a process stream, if that is their function.

4. Provide manual friskers, portal monitors, and half-body contamination monitors in suitable locations. Be sure to provide services for them; for example, a gas-flow proportional counter needs room for its gas bottle and, perhaps, storage for another nearby.

5. Make sure that all airborne monitors are able to detect 8 DAC-hours (under laboratory conditions) as recommended by the Radiological Control Manual.

6. Make sure that all monitors have circuitry that automatically can detect monitor failure and indicate whether the dose rate is off-scale.

7. Provide readouts and alarms that are local, remote, or both, as appropriate (make sure the alarms are both visible and audible where required).

D. Instrumentation.

The ALARA design considerations that follow apply to the instrumentation and control systems disciplines.

1. Select instruments that contain minimal quantities of contaminated working fluid and isolate whenever possible by choosing pressure transducers over bellows-type instruments.

2. Follow good practices for crud deposition reduction.

3. Locate instrument tubing taps on the top half of instrument lines carrying radioactive fluids.

4. Locate all instrumentation, except for primary sensing elements, in low-dose-rate areas and provide for in-place calibration from low-dose-rate areas.

5. Locate pagers, telephones, and other communication systems in a low-dose-rate area.

6. Ensure instruments that must be located in areas of elevated-dose-rates are easily removable for remote repair and calibration in a low-dose-rate area.

7. Provide remote viewing of local readout instruments.

8. Select instruments with features that minimize inspection, calibration, and testing functions.

9. Select high-quality sensors with proven reliability records and low-maintenance requirements for monitoring systems.

10. Provide for logical groupings of readout instruments to decrease time needed for surveillance and logging.

11. Consider using computers for automatic logging.

12. Consider using computers for sensor reliability checks or calibration checks (e.g., smart transmitters).

13. Provide adequate warning systems via flashing light, speakers, or siren for high-radiation sources that can change with time.

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APPENDIX B - ALARA ENGINEERING DESIGN PRINCIPLES

I. ASSESSING RADIATION DOSES

Radiation designs should provide for anticipated dose by including analysis of the tasks and processes that occur in these areas, the anticipated dose rates for the area, and the proposed inventories of radioactive materials.

A. Workers and Time.

Moreover, the numbers of workers and the amount of time they are expected to spend in the area should be taken into consideration.

1. For example, general (low-level) operations areas consist of those areas with small or moderate inventories of radioactive materials. Examples are general radionuclide research labs, rooms containing properly shielded X-ray diffraction and spectroscopy units, and operation areas with low contamination and low dose-rate potential.

2. Work in higher-level operation areas, however, typically involves more radioactive material than does work in general operation areas. Examples of process operation areas are glovebox and hot-cell operating areas, control areas for high-dose rooms, and selected areas of accelerator facilities where experiments with moderate dose or contamination potential cannot be remote-controlled.

B. Multiple Sources.

It is important in building layout to minimize simultaneous dose from multiple sources at locations where maintenance personnel may be required to work. Similarly, individual work stations should be shielded from one another if work by one individual may expose others in the same area to unnecessary dose.

C. Remote Operations.

Functions in remote operation areas are usually remotely or automatically controlled. Occupancy in these areas is predominately for process monitoring or the adjustment of operations occurring in areas of high hazard and restricted access. Examples of this type of area are hot-cell service and maintenance areas and transfer areas where highly dispersible materials of high-dose rate are introduced into the process system or hot cell.

D. Isolation Areas.

Isolation areas include areas with high-dose rates or airborne contamination levels. Unauthorized and unmonitored entry in these areas is forbidden, and design features shall prevent the unauthorized entry of personnel. All personnel are prohibited from entering when conditions in the area present an immediate hazard to human life. Physical controls are required to limit doses when these areas are occupied.

II. ACCESS CONTROL CONSIDERATIONS

Building layout is an important factor in controlling personnel dose by regulating the flow of personnel and material. Proper layout reduces casual or transient exposures to radiation fields by segregating heavily used corridors and the work areas of nonradiological workers from the areas of high radiation and contamination. The layout should effectively limit occupational dose to areas where the performance of an assigned task requires some degree of radiation dose.

Controlled areas defined in 10 CFR 835 are addressed in Module 103. A general discussion follows.

A. Sequential Areas.

An acceptable technique for achieving proper building layout is to establish a system of sequential areas. This concept is frequently used because it is adaptable to the physical control of external and internal dose equivalents. In addition, the design is an excellent precursor to planning and establishing operational radiological control areas.

B. General Access and Controlled Areas.

Two major types of areas are included in any nuclear facility: uncontrolled areas and controlled-access areas.

1. General access: General access areas are normally places to which public access is restricted but where direct radiation exposure is not necessary for job performance, such as the work areas of administrative and nonradiological support personnel. These areas include conference rooms, file rooms, clerical and other support offices, lunch rooms, and rest rooms.

2. Controlled areas: Controlled areas are areas to which access is managed to protect individuals from exposure to radiation and/or radioactive material. Individuals who enter

only the controlled areas without entering radiological areas are not expected to receive a total effective dose equivalent of more than 100 mrem (0.001 sievert) in a year.

Controlled areas may include corridors that are adjacent to, or connected with, areas that contain radioactive materials, change rooms, or special offices for radiation workers.

3. Radiological Area: Any area within a Controlled Area that meets the definition of a Radiation Area, Contamination Area, High Contamination Area, Airborne Radioactivity Area, or High Radiation or Very High Radiation Areas.

   For the purpose of access control, we can divide Radiological Areas into buffer areas (also called contingent areas) and areas of contamination or elevated dose rates.

4. Buffer/contingent areas: Buffer areas should contain offices only if the facility design criteria specify that the offices must be near radiological areas. The primary functions of buffer areas are to control contamination and to isolate radiological areas from general access areas.

C. Traffic.

Locate frequently used pathways in low-radiation areas and noncontaminated areas. (Note: Use common sense and logic. If the pathway is in "clean areas" but in a long and illogical route, people will not use it and may take "short cuts" through hot areas.)

1. Plan transport routes inside and between buildings so that nonradioactive material does not have to pass through radiological areas and *vice versa*.

2. Plan personnel traffic routes so that clean or general access areas are not isolated and do not have to be reached by passing through a radiological area.

3. Plan personnel traffic routes so that access paths between contaminated areas do not pass through clean areas.

4. Consider the sizes and locations of monorails, cranes, doorways, corridors, and hatches in relation to the radiological or nonradiological areas they will serve.

5. Be sure to consider the paths that firefighters will take in entering a radiological area. Try to provide paths that will keep them farthest away from areas of high-dose rate while providing adequate access to the most likely area for a fire.

D. Access.

1. Provide adequate space around components for inspections and maintenance activities.

2. Locate supports so as not to interfere with inspections and maintenance, and facilitate removal of equipment.

3. Provide space and rigging path so that equipment can easily be removed from areas of elevated dose rates for maintenance.

4. Ensure that wide and large enough doorways and access areas are provided so that components can be easily removed for maintenance or inspection.

5. Provide permanent platforms, rigging devices, etc., for easy access to components in hard-to-reach places.

6. Provide laydown space to allow equipment and components to be disassembled.

7. Minimize the number of personnel access control points, and size and equip them for the expected number of workers who will use them.

8. Areas with significant concentration of airborne radioactive materials should be provided with physical barriers to prevent the entry of unauthorized individuals.

9. Provide one of the following features for each entrance or access point to High Radiation Areas:
   a. A control device that prohibits entry when high radiation levels exist, or upon entry causes radiation levels to be reduced below High Radiation Area levels;

   b. A device that prevents operation of the radiation source;

   c. A control device that energizes a conspicuous visible or audible alarm;

d. A locked entry-way; or

e. Continuous surveillance capable of preventing entry.

Additionally, Very High Radiation Areas must prohibit entry when dose rates are greater than posting requirements.

10. Provide panic exit bars on the insides of locked doors as well as locks, alarms, and interlocks as appropriate for areas requiring them.

11. Provide space for temporary access control points where it is anticipated they will be needed from time to time.

12. Provide space, support, and electrical hookups for personnel contamination monitors as needed at each access control point.

E. Radiological Areas.

1. Make contamination and radiation areas as small as possible.

2. Provide for posting of radiological areas and anticipated hot spots.

III. CONTAMINATION CONTROL DESIGN CONSIDERATIONS

A. Contamination Control.

1. Slope floors toward sumps or floor drains and use curbs, dikes, berms, and trenches as appropriate to remove leakage promptly.

2. Hard-pipe drains, tank overflow, valve stem leakage, etc., to sumps.

3. Route drains directly to proper radwaste sumps or tanks.

4. Provide stainless steel collection pans as needed and direct leakage to drains via tubing or piping (stainless steel resists corrosion and facilitates decontamination).

5. Always consider whether flooding (due to leakage, backup of a sump, etc.) may cause the contamination of equipment, and elevate such equipment above flood levels.

6. Use raised sleeves in floor penetrations; consider sealing the penetrations or providing a hood.

7. Avoid using open gratings for stairs or platforms in potentially contaminated areas.

8. Provide space and support for the use of glove bags and other containments over the space created when the head of a heat exchanger is removed, or where a pipe is opened, and in similar cases.

9. Allow room inside and/or near contaminated or potentially contaminated areas for friskers, step-off pads, and used protective clothing bins.

B. Decontamination.

Plan for eventual decontamination. If decontamination is done in place, the worker may experience a high-dose rate from other equipment in the area; he may not have much room to work in; and the decontamination fluids, cloths, and removed parts will have to be collected. If the equipment is removed for decontamination at another location, it may have to be bagged up, lifted, loaded, and moved along a path, possibly passing through general access areas or areas of narrow clearance.

There are several ways to facilitate decontamination during the design phase:

1. Provide smooth, nonporous, and nonreactive surfaces on equipment (inside and out), floors, insulation, walls, trenches, doors, plugs, and tools.

2. Make generous provisions for services to be used for anticipated decontamination: water, air, electricity, and other connections.

3. Provide cleanout openings, taps for hydrolasing or chemical "decon," hatches, collection pans, and means for flushing and draining (be aware that the cleanouts are themselves a crud trap).

4. Consider a central decontamination station for a large facility or operation; size, equip, and locate it for the types, sizes, number, and locations of the equipment it is to handle.

IV. RADIOACTIVE WASTE CONSIDERATIONS

A. Temporary Radwaste Storage.

1. Location for the temporary storage of radioactive wastes must be designed into both the building plan and the plan for each area where radioactive materials are handled.

2. Radioactive material handling areas should be designed with a special area for waste accumulation. This area should be removed from the generally occupied areas of the facility.

3. Special attention should be paid to fire prevention, spill control, and (if necessary) vapor or odor control.

B. Bulk Radwaste Storage.

1. Operating areas should not be the principal areas for interim bulk waste storage. Instead, all major facilities should be designed with a special bulk storage area.

   This area should be located so that wastes being removed from the building will not have to be transported along major personnel traffic routes or through uncontrolled-access areas.

2. To prevent accumulations of waste in operating areas if normal disposal methods are temporarily interrupted, the waste storage area should be large enough to accommodate more than the expected volume of waste.

C. Transport.

1. Plan routes over which solid and liquid wastes in containers must be transported to avoid general access areas as much as possible.

2. Minimize distances over which moderately and highly radioactive wastes are transported from operating areas to disposal points.

D. Drainage of Liquid Systems.

Design drain basins, curbs, and catch or retention tanks for efficient and complete drainage.

E . Monitoring.

Install monitoring systems to detect any leaks or spills in areas where drainage or retention is unattended or is remote-controlled.

F. Fire Suppression.

Install fire-suppression systems in areas where combustible radioactive material may accumulate or be stored. Consider the effects of fires not only in the Radiological Areas, but also in the non-Radiological Areas.

V. SHIELDING, PENETRATIONS, AND ROUTING CONSIDERATIONS

A. Shielding.

1. Obtain information on shielding types, thicknesses, and layout from a radiological specialist (a radiological engineer, ALARA specialist, or health physicist, as appropriate for your project or operation).

2. Don't be reluctant to ask if another type of shielding will do, or if there is a way to accomplish what you want without so much shielding.

3. Labyrinth entrances should be considered for some Radiation Areas, and for all High Radiation and Very High Radiation Areas.

4. Take into account the buildup of the source or other source accumulation over the years (install more shielding than is immediately necessary, or provide space and support for shielding to be added later as the source builds up).

5. Consider removable shielding, such as block walls and ceiling hatches for large equipment, but remember that the removal and re-emplacement will cost some dose. Use proper overlapping and stepping in the design and emplacement of such shielding.

6. Consider temporary shielding when it would be needed only briefly or infrequently (allow for space, support, and transport requirements).

7. Consider special shielding such as shield doors, leaded glass windows, covers for hot spots, transport casks, and shielded carts or forklifts.

8. Add permanent hooks, latches, fasteners, and structural supports to secure temporary shielding.

9. Design shielding to separate components used for processing or storage of radioactive materials to allow for routine operations and maintenance.

B. Penetrations.

1. Have experts from all affected disciplines review a planned penetration before the hole is made.

2. Minimize the size and number of penetrations (several small penetrations are usually better than one big one).

3. Place penetrations in the thinnest shield wall, near a corner, as high up as possible, and not in a line of sight with a source.

4. Place penetrations so they do not line up with accessible areas, including stairways, doorways, and elevators.

5. Place penetrations so they do not line up with any radiation-sensitive equipment, such as electronics, attached to a wall or ceiling on the low-dose-rate side of the penetration.

6. Consider offset penetrations.

7. Provide labyrinths or shadow shields behind penetrations to reduce streaming or scattering through the penetration.

8. Seal penetrations, where justified, for dose-rate reduction, air-flow control, and leakage control.

C. Routing of Ducts, Pipes, Cables, and Conduit (DPCs).

1. Have DPCs enter through a labyrinth or door, if possible.

2. Don't route DPCs containing contaminated fluids through general access areas, or clean DPCs through potentially contaminated or high-dose-rate areas.

3. Locate connections, pull spaces, junction boxes, panels, valve operators, and taps in low-dose-rate areas or at least on the low-dose-rate side of the wall.

4. Provide as short a run of sample and other potentially contaminated lines as possible into the accessible areas.

5. Do not regard the X-Y-Z grid as sacred. Minimize runs of piping by routing diagonally, using bends other then 90 degrees, and sloping lines.

6. Route clean and radioactivity-containing pipes in separate areas, especially pipe tunnels. A worker servicing clean systems should generally not receive significant dose.

7. Route to provide adequate clearance for maintenance, inspection, and insulation.

8. Do not field-route radioactivity-containing DPCs (if it is necessary, guidance should be given to the routers as to the path and areas in which the pipe may go).

9. Make as-built drawings of field-routed piping to ensure that lines containing radioactivity are known and identified.

VI. EQUIPMENT SEPARATION, SEGREGATION, PLACEMENT, AND ISOLATION CONSIDERATIONS

A. Separation.

1. Put shield walls between components sharing the same cubicle to reduce the dose to a worker maintaining one of them (the equipment should be placed so that the worker does not have to pass close to one to get to the other).

2. Separate passive equipment, such as tanks, from active or frequently maintained equipment with shielding.

3. Consider multi-skid designs for appropriate pieces of equipment to allow interstitial shielding (e.g., place shielding between pumps and their motors in highly radioactive streams because the pumps get "hot" while the motors do not).

B. Segregation.

1. Segregate highly radioactive equipment from moderately radioactive equipment, and both from clean equipment. Similarly, segregate equipment with high airborne potential from equipment with less airborne potential, and both from clean equipment.

2. Segregate radioactive equipment of different systems so that both systems will not have to be flushed, drained, or decontaminated to reduce the dose when only one needs maintenance.

C. Placement.

1. Even with shielding, lay out equipment in an area or equipment cubicle so that the worker enters, progresses from low-dose-rate areas to moderate to high-dose-rate areas, and from active to passive equipment.

2. Place inspection, control, and readout devices and panels in low-dose-rate areas.

3. Place services (demineralized water, electricity, etc.) near entrances or at least in the lowest-dose-rate areas.

D. Isolation.

1. Properly place isolation valves to minimize dead legs.

2. Minimize pipe runs in valve aisles (consider reach rods and valve operators).

3. Thoroughly review any proposed interconnection between systems of different radioactivity potential (consider having only temporary connections between radioactive and clean systems, such as the demineralized water supply).

E. Redundancy.

Provide adequate redundancy and backup capability, especially in systems of high radioactivity content and safety systems. Provide appropriate cross-connections to achieve this.

VII. ACCESSIBILITY, LAYDOWN, AND STORAGE CONSIDERATIONS

A. Accessibility.

1. Allow adequate working space around major components, usually at least 3 feet. Do not allow this space to be filled by reach rods, shields, pipes, scaffolds, etc.

2. Provide more space if many workers or large tools are necessary for maintenance, and consider the space taken by protective clothing and respirators.

3. Size labyrinths and doorways to allow the passage of workers, carts, forklifts, and tools.

4. Provide cranes or monorails for large pieces of equipment, pad eyes or anchor points for smaller ones, and lifting lugs on all components of significant weight.

5. Consider permanent galleries or scaffolding where maintenance is frequent or prolonged; provide space and attachments for temporary structures where it is not.

6. Select tanks that have manways sized for a worker wearing a full set of protective clothing, including respirator (preferably at least 24 inches).

7. Supply adequate access around welds by providing prescribed separation between welds and between welds and penetrations.

8. Minimize the number of stops, hangers, supports, and snubbers, and orient them to maximize access space in the area.

9. Consider sectional or modular design (e.g., snap-on segments of insulation on heat-traced lines that require frequent maintenance).

10. Provide space for removal of filters into plastic bags or shielded containers.

B. Laydown and Storage.

1. Provide laydown space in a low-dose-rate area (besides equipment, consider such items as tool boxes, carts, and hoses).

2. Store hot tools (fixed contamination) and tools waiting for decontamination in appropriately posted, locked, shielded, and ventilated areas.

3. Properly store nonradioactive items to be used in radiological areas, such as dosimeters, filters, insulation, and so forth, so that they will not be degraded by radiation, light, moisture, etc.

VIII. SNUBBER, STRUT, HANGER, AND ANCHOR CONSIDERATIONS

1. Locate and design snubbers, struts, hanger, and anchors so as to facilitate removal and replacement.

2. Locate snubbers, struts, hangers, and anchors so as not to interfere with inspections and maintenance.

3. Replace snubbers with struts or energy absorbers whenever possible.

4. Paint and tag snubbers, struts, hangers, and anchors to facilitate location for repair and inspection.

IX. HUMAN FACTORS

A. Consider Visual Factors.

1. Make sure that signs, indicators, readouts, etc., are clearly legible from a reasonable distance away.

2. Avoid the use of nonstandard lettering.

3. Provide adequate lighting and consider auxiliary lighting where equipment is located in a corner or behind other equipment, or where remotely operated cameras are used (provide automatic emergency lighting in areas where the dose rate may be elevated).

B. Consider Auditory Factors.

1. Provide alarms numerous and loud enough to be heard everywhere in the subject area. Also minimize background noise.

2. Provide adequate communications measures, especially in areas where maintenance and inspection workers or health physics technicians may need to communicate with their supervisor or health physicist during a job.

C. Consider Human Physical Characteristics.

1. Familiarize yourself with an appropriate reference on human sizes and physical capacities, and apply this guidance to all design and operations work.

2. Consider the use of lifting devices and special tools so that fewer workers can accomplish a job.

3. Consider the effects of heat stress, particularly with protective equipment such as respirators and/or non-porous protective equipment.

4. Consider provisions for lifelines to pull accidentally injured or unconscious workers from tanks, pools, or other areas of high dose rates or high airborne activity.

D. Help Prevent Human Error.

1. Make permanent alignment marks on the equipment or floor.

2. Color-code tools, conduit, bolts, and pipes.

3. Place identification on insulation to show what is underneath it.

4. Clearly mark system lineup indication of valve position, breaker settings, etc., near controls or equipment.

5. Locate valves, valve operators, controls, etc., in a logical manner.

6. Consider automation of operational sequences, or use interlocks and warning lights for dangerous choices in manual sequences (also use interlocks as an aid to memory, such as automatically starting sample hood HVAC when the sample draw starts).

7. Make it cheap in terms of dose for operations to be accomplished safely (e.g., in areas where the "buddy system" is used for safety, provide a low-dose-rate area where the watcher can observe, perhaps in the labyrinth entrance with a mirror).

8. Consider providing mockups and simulators on which operators can practice for long or complex jobs.

9. Special tools or equipment specific to one area should be provided and kept near that area.

X. OPERATION, MAINTENANCE, AND INSPECTION CONSIDERATIONS

A. Operations.

1. Provide adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc., for operation of equipment.

2. Locate remote operators or reach rods on high-dose-rate valves outside contaminated areas.

3. Locate instrument readouts in low-dose-rate areas and away from contaminated areas whenever possible.

4. Provide for operations and surveillance from outside a High Radiation Area through the use of remote readout devices, viewing ports, radiation detector ports, or TV cameras.

5. Provide access to equipment or instruments requiring frequent manual operation or surveillance via areas with the lowest possible dose rates.

B. Maintenance.

1. Provide adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc., for maintenance.

2. Select the components or systems with long service life, ease of maintenance, reliability, and operating record of low maintenance frequency.

3. Ensure components requiring frequent maintenance (e.g., small pumps and valves) are designed to permit prompt removal (e.g., flanged connections) to facilitate repairs in low-dose-rate areas.

4. Eliminate or minimize periodic maintenance items (e.g., O-rings, gaskets, packing, protective coatings, lighting components).

5. Consider using lubricating systems or self-lubricating units.

6. Provide a mechanism to allow rigging of the component (e.g., pad eyes).

7. Provide access to equipment and components requiring frequent maintenance via areas with lowest dose rates practicable.

8. Ensure that the valve maintenance procedure controls stellite filings to reduce cobalt where neutron activation of the stellite is possible.

9. Design and orient components to minimize crud buildup.

C. Inspection.

1. Provide adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc.

2. Ensure that insulation design allows for rapid removal and replacement (e.g., match marks, fiberglass blankets).

3. Locate equipment with consideration given to facilitating inspections required by Section XI of the ASME Code, Appendix J, Appendix R, and other inspection requirements of the ISI leak rate and fire protection programs.

4. Provide there visible tags and levels to identify equipment, snubbers, welds, penetrations, valves, and other items requiring inspection.

5. Locate access to equipment or components requiring frequent inspections via areas with lowest possible dose.

APPENDIX C - CALCULATIONS INVOLVING THE QUANTITIES USED IN 10 CFR PART 835

Perhaps the best way to understand the dosimetric methodology of 10 CFR 835 (which is based on ICRP Publication 26) is to learn the way the calculations are performed. Anyone who has mastered simple arithmetic and is willing to give some thought to the subject can perform these computations.

I. DEFINITIONS AND BASIC RELATIONSHIPS

Definitions

In 10 CFR 835, the rem is used as the unit of measurement for the physical quantities listed below. Remember that just as the *meter* is the unit for the quantity *distance*, and the *liter* is the unit for the quantity *volume*, so too is the *rem* (or *sievert, Sv*) the unit for the quantity *dose equivalent*.

A. **Dose Equivalent (H, H_T)**: The product of absorbed radiation dose, a radiation quality factor (Q), and other modifying factors. Dose equivalent may be specified for the whole body using the symbol "H," or it may be designated for a specific tissue or organ, T[1], by using the symbol "H_T."

B. **Deep Dose Equivalent (DDE)**: The dose equivalent derived from external radiation at a depth of 1 cm in tissue.

C. **Lens of the Eye Dose Equivalent (LDE)**: The external exposure of the lens of the eye; it is taken as the dose equivalent at a tissue depth of 0.3 cm.

D. **Shallow Dose Equivalent (SDE)**: The dose equivalent deriving from external radiation at a depth of 0.007 cm in tissue.

E. **Committed Dose Equivalent ($H_{T,50}$)**: The dose equivalent (H) calculated to be received by a tissue or organ (T) over a 50-year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body.

[1]Tissues and organs include: gonads, breasts, red bone marrow, lungs, thyroid, bone surfaces, and remainder organs.

F. **Effective Dose Equivalent (H_E)**: The summation of the products of the dose equivalent received by specified tissues or organs of the body (H_T) and the appropriate weighting factor for that tissue or organ (w_T)[2] - that is $\sum w_T H_T$.

G. **Committed Effective Dose Equivalent ($H_{E,50}$)**: The sum of the committed dose equivalents to various tissues and organs in the body ($H_{T,50}$), each multiplied by the appropriate weighting factor (w_T) - that is $H_{E,50} = \sum w_T H_{T,50}$.

H. **Total Effective Dose Equivalent (TEDE)**: The sum of the effective dose equivalent (H_E) for external exposures and the committed effective dose equivalent ($H_{E,50}$) for internal exposures. For purposes of compliance with 10 CFR 835, Deep Dose Equivalent (DDE) to the whole body may be used as H_E for external exposures.

Other important definitions listed in 10 CFR 835 that are important in dosimetry calculations include:

I. **Annual Limit on Intake (ALI)**: The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the Reference Man (ICRP Publication 23) that would result in a Committed Effective Dose Equivalent of 5 rem or a Committed Dose Equivalent of 50 rem to any individual organ or tissue. Since the ALI is a radioactivity quantity, its units are *curies (Ci)*.

J. **Derived Air Concentration (DAC)**: The airborne concentration of radionuclides that equals the ALI for an individual radionuclide divided by the volume of air breathed by an average worker for a working year of 2,000 hours. The DAC is a concentration quantity with typical units of *microcurie per milliliter (μCi/ml).*

A useful quantity that is not defined in 10 CFR 835, but is very useful in the application of these dosimetry concepts is the DAC-hour:

K. **DAC-hour (DAC-hr)**: The time spent by a worker in an airborne radioactivity concentration multiplied by the ratio of that concentration to the appropriate DAC. For example, a worker

[2]Weighting factors, W_T, are listed in 10 CFR 835 for specific organs and tissues.

who works for 8 hours in an area with an airborne radioactivity concentration of 1 DAC would have spent 8 DAC-hrs in the area. If the worker worked for 8 hours in an area with an airborne radioactivity concentration of 10 DAC, he would have spent 80 DAC hours in the area. A total of 2,000 DAC-hrs would result in a Committed Effective Dose Equivalent of 5 rem or a Committed Dose Equivelent of 50 rem to any individual organ or tissue.

II. CALCULATIONS INVOLVING THE DOSIMETRY QUANTITIES

A. 10 CFR 835 Limits.

10 CFR 835 sets the following annual limits with regards to occupational exposure of general employees:

1. Total Effective Dose Equivalent

   TEDE $\leq$ 5 rem

2. Deep Dose Equivalent and Committed Dose Equivalent to any organ or tissue.

   DDE + $H_{T,50} \leq$ 50 rem (T other than lens of eye)

3. Lens of Eye Dose Equivalent

   LDE $\leq$ 15 rem

4. Shallow Dose Equivalent

   SDE $\leq$ 50 rem (to the skin or any extremity)

B. Combining Internal and External Exposures.

The TEDE during a year shall be determined by summing Effective Dose Equivalent from external exposures and the Committed Effective Dose Equivalent from intakes during the year. For purposes of compliance, the Deep Dose Equivalent to the whole body may be used as Effective Dose Equivalent for external exposures.

$$TEDE = H_E + H_{E,50}$$

or

$$TEDE = DDE + H_{E,50}$$

C. Calculating Internal Exposure Using ALIs and DACs.

Internal exposures are typically determined by evaluation of bioassay results. For the purposes of ALARA planning, it is beneficial to be able to calculate or estimate what an individual's internal exposure would be based on air concentrations.

Begin by understanding the relationship between the DAC and the ALI:

$$DAC\ (\mu Ci/ml) = \frac{ALI\ (Ci)}{2400 m^3}$$

The average worker breathes approximately 2400 m^3 of air during a 2,000-hour working year.

If C is the actual radioactivity concentration in which a worker is breathing, the Committed Effective Dose Equivalent ($H_{E,50}$) may be calculated directly from air concentration measurements and using the DAC value found in 10 CFR 835 for the radionuclide being inhaled and the time that was spent in the area.

For example: Where the limiting ALI is based on 5 rem CEDE:

$$H_{E,50}(rem) = \frac{C\ (\mu Ci/ml)}{DAC\ (\mu Ci/ml)} \times \frac{time\ (hrs)}{2000 hrs} \times 5 rem$$

Individuals may enter areas with airborne radioactivity concentrations greater than the DAC for specific radionuclides; however, their time spent in such an area must be limited so that TEDE $\leq$ 5 rem and CDE $\leq$ 50 rem. In this case, it is easier to use the DAC-hour quantity to calculate $H_{E,50}$.

For example: Where the limiting ALI is based on 5 rem CEDE:

$$H_{E,50}(rem) = \frac{DAC\text{-}hrs}{2000hrs} \times 5rem$$

or

$$H_{E,50}(mrem) = DAC\text{-}hrs \times 2.5mrem/hr$$

If a worker spent 8 hours in an area in which the airborne radioactivity concentration was 3 DAC, based on the limiting ALI of 5 rem CEDE, his Committed Effective Dose Equivalent ($H_{E,50}$) would be calculated as follows:

$$DAC\text{-}hrs = 3DAC \times 8hrs = 24DAC\text{-}hrs$$

$$H_{E,50}(mrem) = 24DAC\text{-}hrs \times 2.5mrem/hr = 60mrem$$

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APPENDIX D - ALARA DESIGN REVIEW CHECKLIST

(Insert facility-specific checklist or documents or substitute facility-specific information, as applicable.)

A. Overview.

As an aid in performing an ALARA Design Review, series checklists have been provided here.

The first part (Sections I) is a list of preliminary questions called "First Level Screening Questions" that serves to sort out which groups of questions in the main checklist will need to be answered. The second part (Section II-XXI) is the main checklist, a series of questions grouped by subject. These checklists include space where individual answers may be discussed and resolutions may be recorded.

B. Filling Out the Checklist.

1. If there is any doubt regarding the applicability of an issue or an ALARA principle being neglected, the reviewer should answer conservatively (i.e., answer to indicate an issue IS involved or that ALARA IS being neglected).

2. Where a question is not applicable, the reviewer should answer "N/A."

3. The reviewer can call the ALARA Review Coordinator for guidance in responding to questions.

4. The questions are to be answered considering not only new or newly added features, but also existing features that might be affected. The impact of nonradiological additions on radiological items also must be considered.

I. ALARA PRELIMINARY SCREENING QUESTIONS

A.	Does the facility, system, or subject include:	YES	NO
1.	Entry into or activity in or near a Radiological Area?		
	Resolution:		
	Response:		
2.	Shielding; penetrations; equipment separation or segregation; or routing of pipes, conduit, or ducts?		
	Resolution:		
	Response:		
3.	Location of sensors, readouts, or like manual-access or visual-access components in a Radiological Area?		
	Resolution:		
	Response:		
4.	Activities which may affect ventilation equipment (such as selection and maintenance), produce airborne contamination, or other require local ventilation or airborne controls?		
	Resolution:		
	Response:		
5.	Construction or assembly techniques, materials, shapes, flow patterns, or choices of equipment which potentially contribute to crud or other radioactivity production or accumulation?		
	Resolution:		
	Response:		

A.	Does the facility, system, or subject include:	YES	NO
6.	Flow paths or contact surfaces which might require isolation or decontamination, or measures to facilitate decontamination?		
	Resolution:		
	Response:		
7.	Radiation monitoring or sampling systems, or modifications which may result in the need to alter or add such systems?		
	Resolution:		
	Response:		
8.	Radwaste collecting or processing systems, or modifications which will result in additional radwaste or different forms of radwaste being sent to these systems?		
	Resolution:		
	Response:		
9.	Access, laydown, or storage space for installation, removal, maintenance, inspection, or calibration?		
	Resolution:		
	Response:		
10.	Lighting, access sizing, noise levels, communications, signaling, labeling, or other human factor considerations?		
	Resolution:		
	Response:		

A.	Does the facility, system, or subject include:	YES	NO
11.	Component or design features that may cause significant radiation exposures during installation, removal, maintenance, or operation, or measures to reduce such exposures?		
	Resolution:		
	Response:		
12.	Component or design features that may cause a significant change in the dose to the public, whether by direct radiation or by releases to the environment?		
	Resolution:		
	Response:		

II. GENERAL ALARA CHECKLISTS

A.	Materials of Construction	YES	NO
1.	Are material specifications established to decrease the formation of activated materials (e.g., by specifying materials low in cobalt and nickel content where applicable?		
	Resolution:		
	Response:		
2.	Are surfaces smooth and/or painted for easy decontamination?		
	Resolution:		
	Response:		
3.	Are rough surface finishes such as crevices, holes, notches, recesses, socket-head cap screws, and knurled finishes avoided?		
	Resolution:		
	Response:		

B.	Shielding	YES	NO
1.	Is shielding placed between serviceable components and any substantial radiation source in the area?		
	Resolution:		
	Response:		
2.	If permanent shielding is not feasible, are provisions incorporated for rapid installation of temporary shielding (i.e., shield racks or supports)?		
	Resolution:		
	Response:		
3.	Are shields employed to prevent streaming of radiation through doors, pipes, and duct penetrations (e.g., labyrinths or shadow shields)?		
4.	Is an adequate safety margin applied to seismic load analysis to accommodate the additional load from temporary shielding?		
C.	Access Control	YES	NO
1.	Are traffic pathways and areas that will be frequently used located in low radiation zones?		
	Resolution:		
	Response:		
2.	Are areas of the facility that exhibit high occupancy, or are presently uncontrolled, adequately protected from new or increased radiation sources?		
	Resolution:		
	Response:		

C.	Access Control	YES	NO
3.	Is maximum distance provided between serviceable components and any substantial radiation sources in the area?		
	Resolution:		
	Response:		
D.	Contamination Control	YES	NO
1.	Can containment be established to reduce the spread of contamination (i.e., glovebags, cribs, catch pans, drip pans, or cofferdams)?		
	Resolution:		
	Response:		
2.	Are HEPA filters and/or charcoal used on the exhaust in areas that have the potential for airborne radioactivity?		
	Resolution:		
	Response:		
3.	Are the pressure gradient and airflow such that air flows from areas of low potential for airborne radioactivity to areas of higher potential for airborne radioactivity?		
	Resolution:		
	Response:		
4.	Does the design incorporate features that will reduce the likelihood of cross-contamination of clean systems and unmonitored release pathways?		
	Resolution:		
	Response:		

E.	Service Readiness	YES	NO
1.	Is the equipment ready for service as received?		
	Resolution:		
	Response:		
2.	Does the equipment require modification prior to installation? If so, is the modification reflected in applicable documents, and can the modification be performed in a non-radiologically controlled area?		
	Resolution:		
	Response:		
F.	Documentation	YES	NO
1.	Are all changes, revisions, modifications, and configurations clearly reflected in applicable documents?		
	Resolution:		
	Response:		

III. ALARA INSTALLATION REVIEW QUESTIONNAIRE

A.	Engineering Techniques	YES	NO
1.	Have special equipment, tools, convenience features (e.g., lighting, communications, staging, laydown areas, etc.), and engineering techniques that may minimize exposures been considered?		
	Resolution:		
	Response:		

A.	Engineering Techniques	YES	NO
2.	Have other engineered controls (such as prefabrication of work outside radiation area, robotic equipment, snap-tight connectors, etc.) Been considered to reduce exposure?		
	Resolution:		
	Response:		
B.	Installation Procedures	YES	NO
1.	Have installation procedures been prepared or modified to minimize exposures?		
	Resolution:		
	Response:		
2.	Have radiation protection hold points, radiological requirements for the job, listing of tools used on the job, and a step-by-step installation process been included in installation procedures?		
	Resolution:		
	Response:		
C.	Shielding	YES	NO
1.	Have components/areas where shielding (including shadow and portable) might be effectively used to reduce exposures been considered?		
	Resolution:		
	Response:		
2.	For installations or modifications in high-dose-rate areas, have special or customized shields been designed and fabricated to reduce the dose to workers, where appropriate?		
	Resolution:		
	Response:		

D.	Decontamination and Contamination Control.	YES	NO
1.	Have components, systems, and areas been considered for decontamination to reduce exposures and the spread of contamination (e.g., hydrolyzing, chemical decontamination, flushing, etc.)?		
	Resolution:		
	Response:		
2.	Have any special local ventilation, containment, or spray systems been considered that can reduce the spread of radioactivity (e.g., tents, gloveboxes, filtered blowers, etc.)?		
	Resolution:		
	Response:		
E.	Planning.	YES	NO
1.	Have installation and construction plans been developed to optimize the efficiency of the work?		
	Resolution:		
	Response:		
2.	Have installation and construction plans taken advantage of facility system (not specific enough) configuration and operating conditions (e.g., resin transfer, fuel out of vessel, etc.)?		
	Resolution:		
	Response:		
3.	Have installation and construction plans included measures to minimize radwaste generation by unpacking equipment outside of radiological areas, pre-treating wood, etc.?		
	Resolution:		
	Response:		

F.	Scheduling.	YES	NO
1.	Have radiological hold points and ALARA controls been factored into the installation and construction schedule (e.g., surveys, decon, shielding, containment, ventilation systems, etc.)?		
	Resolution:		
	Response:		
2.	Has work been scheduled so as not to interfere with concurrent work in the same area?		
	Resolution:		
	Response:		

IV. HEATING, VENTILATION, AND AIR CONDITIONING SYSTEM CHECKLISTS

		YES	NO
1.	Are welded seams employed in ductwork carrying contaminated air?		
	Resolution:		
	Response:		
2.	Has HVAC equipment been leak tested after installation and repair?		
	Resolution:		
	Response:		
3.	Are filters appropriate to the operation and radionuclides present?		
	Resolution:		
	Response:		

4.	Are differential pressure detectors provided across filters to monitor dust loading?		
	Resolution:		
	Response:		
5	Have open-topped tanks or tanks with vent lines lower than overflow lines been avoided?		
	Resolution:		
	Response:		
6.	Has hard-piping to HVAC of relief valves and vents been avoided, where appropriate, except with proper additional provisions?		
	Resolution:		
	Response:		
7.	Have filters on highly radioactive systems been designed to minimize dose from the spread of contamination during changeout (e.g., filter bagout, located for each access, etc.)?		
	Resolution:		
	Response:		
8.	Is water used for back-flushing and unplugging, rather than compressed gas?		
	Resolution:		
	Response:		
9.	Have penetrations, gratings, construction openings, etc., been evaluated for proper placement and sealing when open to areas of potential airborne activity?		
	Resolution:		
	Response:		

10.	Are sealed-bearing motors with the motor mounted external to the exhaust duct provided? Are the motors located in a low-dose-rate area?		
	Resolution:		
	Response:		
11.	Is intake air filtered to minimize dust accumulation in radiological areas and exhaust filter loading?		
	Resolution:		
	Response:		
12.	Have auxiliary or temporary ventilation systems been provided for sampling stations for highly radioactive fluids (e.g., primary coolant) and for repair of equipment that, when opened, has a potential for airborne releases? (Consider both temporary ductwork attached to existing systems and independent, portable HEPA-filtered ventilation systems.)		
	Resolution:		
	Response:		
13.	Does ventilation from areas of lower potential airborne radioactivity flow to areas of higher potential activity?		
	Resolution:		
	Response:		
14.	Are all ducts carrying potentially contaminated air operated at negative pressure when they pass through clean areas?		
	Resolution:		
	Response:		

15.	Are ventilation supply points located above the worker or work area and away from the sources of contamination, or otherwise placed as appropriate for the work activity (e.g., for work tables, gloveboxes, and hoods)?		
	Resolution:		
	Response:		
16.	Has the drawing or exhausting of potentially contaminated air across walkways and work areas been avoided?		
	Resolution:		
	Response:		
17.	Are ventilation exhausts located near the floor and away from entrances of openings to clean areas, or otherwise placed as appropriate for the work activity (e.g., for work tables, gloveboxes, and hoods)?		
	Resolution:		
	Response:		
18.	Are ventilation fans located as close as possible to the discharge point and downstream of the filters?		
	Resolution:		
	Response:		
19.	Has the number of elbows in the ventilation ducts been minimized to reduce plateout?		
	Resolution:		
	Response:		

20.	Are the direction changes in ductwork gradual and minimized?		
	Resolution:		
	Response:		
21.	Are ducts and fans sized so that flow rates are high enough to reduce plateout?		
	Resolution:		
	Response:		
22.	Has special materials or coating of inner surfaces been considered to reduce plateout?		
	Resolution:		
	Response:		
23.	In flow balancing, have effects such as opening and closing of large doors, which may occur during normal operation or shutdown, been considered, and are the capacity and flexibility of the ventilation system(s) capable of overcoming these effects?		
	Resolution:		
	Response:		
24.	Is ventilation flow sufficient to keep airborne radioactivity concentrations below prescribed levels?		
	Resolution:		
	Response:		

25.	Have connections been provided to attach temporary ventilation systems where additional ventilation flow may be needed?		
	Resolution:		
	Response:		
26.	Is the ventilation system designed to minimize the use of respirators?		
	Resolution:		
	Response:		
27.	Have HEPAs, charcoal filters, electrostatic precipitators, molecular sieves, or other air-cleaning devices been provided as appropriate?		
	Resolution:		
	Response:		
28.	Are filters located as close to the source as practicable, and upstream of any fans, to reduce contamination buildup in the ductwork and fans?		
	Resolution:		
	Response:		
29.	Are roughing filters provided upstream of HEPA filters, and are HEPA filters provided upstream of charcoal filters?		
	Resolution:		
	Response:		

30.	Are there drains/dryer/moisture separators upstream of filters and charcoal?		
	Resolution:		
	Response:		
31.	Are there provisions for decontamination of filter housing and ventilation ducts?		
	Resolution:		
	Response:		
32.	Are filters for highly contaminated ventilation systems located in shielded housing or in low-occupancy and low-traffic areas?		
	Resolution:		
	Response:		
33.	Can airborne activity and filter radiation levels be monitored or sampled without physically entering the area? Are differential pressure gauges provided across filters to monitor the need for filter change?		
	Resolution:		
	Response:		
34.	Are ventilation motors located in low-dose areas?		
	Resolution:		
	Response:		

35.	Does the ventilation system permit filters to be changed easily and with a minimum potential for release of radioactivity and worker exposure?		
	Resolution:		
	Response:		
36.	Is there the capability for in-place testing of the filtration system?		
	Resolution:		
	Response:		
37.	Are all airborne and potentially airborne radioactivity areas vented to a monitored release point?		
	Resolution:		
	Response:		
38.	Are connections provided for sampling probes in isokinetic locations, where required?		
	Resolution:		
	Response:		
39.	Can filter housing and filters be removed remotely or quickly in the event of an accident?		
	Resolution:		
	Response:		
40.	Are key ventilation systems provided with emergency power?		
	Resolution:		
	Response:		

41.	Have adequate capacity and volume of HEPA and charcoal filters been provided to handle conditions during abnormal operations?		
	Resolution:		
	Response:		

V. PIPING AND TUBING CHECKLIST

		YES	NO
1.	Are piping run lengths, tees, elbow joints, and horizontal runs minimized?		
	Resolution:		
	Response:		
2.	Has tee-branched piping been routed above the main flow piping or sloped upwards?		
	Resolution:		
	Response:		
3.	Are sharp constrictions, sharp bends crud traps, and stagnant legs avoided?		
	Resolution:		
	Response:		
4.	Are surfaces smooth and continuously sloped?		
	Resolution:		
	Response:		

5.	Has piping carrying resin or sludge been designed to reduce the chance of plugging?		
	Resolution:		
	Response:		
6.	Are materials selected to minimize activation products?		
	Resolution:		
	Response:		
7.	Has piping carrying highly radioactive fluids been routed away from equipment and components requiring frequent maintenance or repairs?		
	Resolution:		
	Response:		
8.	Has piping carrying highly radioactive fluids been routed in shielded chases or inside shielded cubicles that have restricted access?		
	Resolution:		
	Response:		
9.	Has piping carrying radioactive fluids been segregated from piping not carrying radioactive fluids?		
	Resolution:		
	Response:		

10.	Have adequate controls been established to prevent cross-contamination of clean, nonradioactive systems?		
	Resolution:		
	Response:		
11.	Are pipes and leakage plumbed to drains; and vents to ventilation ducting? Has pressurization of the system been considered?		
	Resolution:		
	Response:		
12.	Have piping and components been selected that will maintain containment over the environment qualification range to prevent release of radioactivity to the offsite environment?		
	Resolution:		
	Response:		
13.	Has field routing of piping carrying radioactive fluids been avoided?		
	Resolution:		
	Response:		
14.	Have piping and components requiring maintenance been located in low-dose-rate areas?		
	Resolution:		
	Response:		

15.	Has an adequate number of vents and drains been required to allow system testing, maintenance, and operations?		
	Resolution:		
	Response:		
16.	Have consumable inserts for welding been specified for pipes carrying radioactive materials?		
	Resolution:		
	Response:		
17.	Have butt welds rather than socket welds been used for pipes greater than 1.5 inches?		
	Resolution:		
	Response:		
18.	Are pipe bends at least five pipe diameters in radius for the transfer of resin and sludge?		
	Resolution:		
	Response:		
19.	Is instrument tubing that taps into pipes carrying primary coolant located on the top half of the pipe?		
	Resolution:		
	Response:		
20.	Are remote techniques available to unclog plugged drain lines or instrumentation tubing?		
	Resolution:		
	Response:		

21.	Has removable pipe insulation been specified in areas requiring in-service inspection?		
	Resolution:		
	Response:		
22.	Are techniques available to periodically flush, hydrolase, or chemically decontaminate piping? Is the flush connection equipped with quick disconnect fittings?		
	Resolution:		
	Response:		

VI. FILTER, STRAINER, EVAPORATOR, AND ION EXCHANGER CHECKLIST

		YES	NO
1.	Are filters provided upstream of deep-bed demineralizers to extend resin life and reduce radioactive waste volume?		
	Resolution:		
	Response:		
2.	Are strainers provided downstream of filters and demineralizers to entrain stray fines?		
	Resolution:		
	Response:		
3.	Have demineralizers and resin storage tanks been located so as to facilitate resin flow and reduce the length of pipe needed?		
	Resolution:		
	Response:		

4.	Are filters or strainers backflushable?		
	Resolution:		
	Response:		
5.	Does resin slurry piping have backflushing capabilities with sufficient velocity to relieve plugged lines?		
	Resolution:		
	Response:		
6.	Can containment or ventilation be established to reduce the spread of contamination during filter, strainer, or evaporator tube cleaning resin changes?		
	Resolution:		
	Response:		
7.	Are screens filters, or other catch devices placed in the vent and overflow lines? Is pressurization of the system considered?		
	Resolution:		
	Response:		
8.	Is concentrate and distillate piping on evaporators kept separated and segregated?		
	Resolution:		
	Response:		

9.	Are filters, strainers, evaporators, and ion exchangers that contain high radioactivity isolated or shielded?		
	Resolution:		
	Response:		
10.	Are filters, strainers, evaporators, and ion exchangers located in low-occupancy and low-traffic areas?		
	Resolution:		
	Response:		
11.	Have filters, strainers, evaporators, ion exchangers, and other related routinely serviced items been selected to be compatible with existing equipment?		
	Resolution:		
	Response:		
12.	Are filter and strainer easily removable?		
	Resolution:		
	Response:		
13.	Has adequate space been provided for removal of filters, strainers, and heating tube bundles?		
	Resolution:		
	Response:		
14.	Have quick disconnects been provided for quick flush connection?		
	Resolution:		
	Response:		

15.	Do filters that process high radioactivity containing water or offgas have remote methods to isolate and drain filter housing?		
	Resolution:		
	Response:		
16.	Have remote or shielded methods for replacement of hot filters, strainers, and resins been considered?		
	Resolution:		
	Response:		
17.	Are systems supplied with flush connections that will facilitate high-velocity decontamination/chemical flushes?		
	Resolution:		
	Response:		

VII. TANK, SUMP, AND FLOOR AND EQUIPMENT DRAIN CHECKLIST

1.	Are tanks generously sized?		
	Resolution:		
	Response:		
2.	Is the tank, drain, or sump bottom sloped to the outlet?		
	Resolution:		
	Response:		

3.	Are corners in tanks eliminated or minimized?		
	Resolution:		
	Response:		
4.	Is adequate tank mixing provided to prevent crud from settling on the bottom?		
	Resolution:		
	Response:		
5.	On tanks containing resins or sludge, are screens or strainers provided on tank vents and overflows? Is the overflow line lower than the tank's vent?		
	Resolution:		
	Response:		
6.	Is the tank vent outlet located near a plant ventilation system inlet?		
	Resolution:		
	Response:		
7.	Has curbing or other containment been considered to restrict the spread of leakage? Is curbing or other containment required to prevent an unmonitored release?		
	Resolution:		
	Response:		
8.	Are radioactive tanks or sumps located or shielded so as to minimize personnel exposure?		
	Resolution:		
	Response:		

9.	Are piping run lengths, tees, elbow joints, and horizontal runs minimized?		
	Resolution:		
	Response:		
10.	Are pipes sized to reduce crud deposition?		
	Resolution:		
	Response:		
11.	Is the flow adequate to maintain homogeneity and keep solids in suspension?		
	Resolution:		
	Response :		
12.	Are full-ported valves used in radioactive fluid streams with high-solids contents?		
	Resolution:		
	Response:		
13.	Are automated valves used to ensure continued flow after a backwash or precoat?		
	Resolution:		
	Response:		
14.	Is a “recirc” line provided to ensure good mixing before tank transfer?		
	Resolution:		
	Response:		

15.	Are the interior surfaces smooth and free of pockets to facilitate decontamination?		
	Resolution:		
	Response:		
16.	Are pipes containing radioactive material isolated from uncontrolled areas?		
	Resolution:		
	Response:		
17.	Are transfer lines located in low-occupancy and low-traffic areas?		
	Resolution:		
	Response:		
18.	Does adequate space exist for maintenance and repair of tank support equipment (e.g., pumps, agitators, gear boxes)?		
	Resolution:		
	Response:		
19.	Have decontamination methods been considered?		
	Resolution:		
	Response:		
20.	Are lap joints and backing rings avoided on welds?		
	Resolution:		
	Response:		

21.	Is a built-in spray system, manway with adequate laydown space, drain or flush system included for cleanout?		
	Resolution:		
	Response:		

VIII. HEAT EXCHANGER, MOISTURE SEPARATOR, AND HEATER CHECKLIST

		YES	NO
1.	Are drains provided at the low point so as to drain out radioactive crud and facilitate cleaning?		
	Resolution:		
	Response:		
2.	Are vessels designed such that crud traps are minimized in those areas where access is needed for inspection and cleaning?		
	Resolution:		
	Response:		
3.	Have materials been selected to minimize corrosion?		
	Resolution:		
	Response:		
4.	Are heat exchangers oriented in the vertical position?		
	Resolution:		
	Response:		

5.	Is the pressure higher on the side with the lower concentration of radioactivity so that leakage would result in nonradioactive water leaking into the radioactive system rather than the reverse?		
	Resolution:		
	Response:		
6.	Have curbing and drains been provided to contain radioactivity during repair and cleaning?		
	Resolution:		
	Response:		
7.	Is the fluid with the high concentration of radioactivity inside the tube so that the water on the shell side provides shielding?		
	Resolution:		
	Response:		
8.	Are heat exchangers that are expected to become highly radioactive placed inside shielded cubicles and provided with a flushing or decontamination capability?		
	Resolution:		
	Response:		
9.	Has adequate space and component design been provided to facilitate removal and cleaning of tube bundles and/or shell?		
	Resolution:		
	Response:		

IX. ELECTRICAL CABLE AND CONDUIT CHECKLIST

		YES	NO
1.	Has a walkdown or photographs that may aid in locating conduit runs in low-dose-rate and low-interference areas been considered?		
	Resolution:		
	Response:		
2.	Have cable and conduit been routed in low-dose-rate areas?		
	Resolution:		
	Response:		
3.	Have breaker boxes, power control centers, and electrical cabinets been located in low-dose-rate areas?		
	Resolution:		
	Response:		
4.	Are long-life bulbs used in radiation and contamination areas?		
	Resolution:		
	Response:		
5.	Has electrical equipment been selected that minimizes inspection, calibration, testing, and preventative maintenance?		
	Resolution:		
	Response:		

6.	Do electrical connectors to equipment have quick-disconnect features, where appropriate?		
	Resolution:		
	Response:		
7.	For electrical systems that are difficult to inspect or troubleshoot, has external analysis capability been considered for fault location determination?		
	Resolution:		
	Response:		
8.	Can busses, conduit, supports, trays, and electrical cabinets be prefabricated in a low-dose-rate area?		
	Resolution:		
	Response:		
9.	Are sufficient electrical outlets provided for air-sampling devices, electrical tools, welding machines, and temporary distribution boxes?		
	Resolution:		
	Response:		
10.	Have adequate lighting and electrical outlets, as well as provisions for supplementary and emergency lighting, been provided?		
	Resolution:		
	Response:		

11.	Does conduit or other electrical equipment interfere with the maintenance or operation of other equipment?		
	Resolution:		
	Response:		

X. INSTRUMENTATION AND CONTROLS CHECKLIST

		YES	NO
1.	Are bends in sample lines minimized?		
	Resolution:		
	Response:		
2.	Are sample lines in high radioactivity systems provided with a strong and continuous purge?		
	Resolution:		
	Response:		
3.	Does the ventilation hood have a face velocity of 100-150 linear feet per minute with the hood window in its full open position?		
	Resolution:		
	Response:		
4.	Is the ventilation hood exhaust directed to the facility vent upstream of the filters?		
	Resolution:		
	Response:		

5.	Are sampling sink drains for radioactive samples routed to radwaste and free of potential crud traps?		
	Resolution:		
	Response:		
6.	Are the sampling sinks for radioactive materials constructed of a material or coated such that they will be easy to decontaminate?		
	Resolution:		
	Response:		
7.	Are routine sampling stations for radioactive materials separated or shielded from other radioactive components?		
	Resolution:		
	Response:		
8.	Are the sample stations adequately shielded?		
	Resolution:		
	Response:		
9.	Is cross contamination of nonradioactive systems minimized and/or monitored?		
	Resolution:		
	Response:		

10.	Are monitors visible?		
	Resolution:		
	Response:		
11.	Have methods been provided to perform remote sampling and monitoring for airborne radioactivity?		
	Resolution:		
	Response:		
12.	Are process and effluent monitors located as to provide enough detection leak time to divert or isolate a process stream?		
	Resolution:		
	Response:		
13.	Are personnel monitors provided?		
	Resolution:		
	Response:		
14.	Are airborne radioactivity monitors capable of detecting 8 DAC-hours?		
	Resolution:		
	Response:		
15.	Do all monitors automatically detect monitor failure and indicate if the dose rate is off-scale?		
	Resolution:		
	Response:		

16.	Are monitors provided with readouts and alarms?		
	Resolution:		
	Response:		
17.	Are flush connections provided for instrumentation lines carrying radioactive fluid in which crud traps cannot be avoided?		
	Resolution:		
	Response:		
18.	Do instruments contain minimal quantities of contaminated working fluids?		
	Resolution:		
	Response:		
19.	Are instrument tubing taps located on the top half of instrument lines carrying radioactive fluids?		
	Resolution:		
	Response:		
20.	When access is necessary, is instrumentation located in what will be a low background area? Have remote readouts (or closed circuit TV monitoring) and calibrations been considered?		
	Resolution:		
	Response:		

21.	Have communication devices such as pagers and telephones been located in low-dose-rate areas and low-noise areas?		
	Resolution:		
	Response:		
22.	Are instruments located in High Radiation Areas easily removable for repair and calibration?		
	Resolution:		
	Response:		
23.	Are instruments grouped functionally to minimize time for surveillance and calibration?		
	Resolution:		
	Response:		
24.	Does the instrument selected take into account frequency of maintenance, repair, testing, and calibration?		
	Resolution:		
	Response:		
25.	Have instruments been selected with features of computerized or automated data loggings (applicable)?		
	Resolution:		
	Response:		

26.	Are warning systems such as lights, alarms, and sirens provided in areas where high radiation levels can change with time?		
	Resolution:		
	Response:		
27.	Have instruments been chosen that are radiation qualified for the areas they are to function in?		
	Resolution:		
	Response:		

XI. PUMP CHECKLIST

		YES	NO
1.	Is there a capability to flush seals and cooling lines that carry radioactive fluids?		
	Resolution:		
	Response:		
2.	Have catch pans or floor and equipment drains or curbing berms been installed around radioactive pumps that have a potential for leakage?		
	Resolution:		
	Response:		
3.	Do pump casings have drain connections, and are impellers fabricated with smooth surface finishes?		
	Resolution:		
	Response:		

4.	Have pump maintenance requirements been considered?		
	Resolution:		
	Response:		
5.	Have canned pumps or mechanical seals been considered instead of standard packing glands?		
	Resolution:		
	Response:		
6.	Are pump seals easily accessible and replaceable?		
	Resolution:		
	Response:		
7.	Can the pump be removed without affecting the surrounding components?		
	Resolution:		
	Response:		
8.	Is there adequate pull space for motor shafts?		
	Resolution:		
	Response:		
9.	Are pumps that are located in High Radiation Areas and require periodic repair or maintenance been provided with flanged connections to make them easy to remove?		
	Resolution:		
	Response:		

10.	Have rigging and lifting points been provided to life heavy pump parts during repair?		
	Resolution:		
	Response:		
11.	Are pumps oriented to permit easy access?		
	Resolution:		
	Response:		

XII. VALVE CHECKLIST

		YES	NO
1.	Are valves full-ported (e.g., ball valves), without bonnet cavities, installed stem up, and located away from low points in piping?		
	Resolution:		
	Response:		
2.	Are valves selected with internal surfaces and configurations that will minimize crud buildup?		
	Resolution:		
	Response:		
3.	Are materials selected to minimize activation products and are stellite filings controlled?		
	Resolution:		
	Response:		

4.	Do specified valve packing and seals result in minimal contaminated coolant leakage and maximum reliability (e.g., live-loaded packing)?		
	Resolution:		
	Response:		
5.	Are check valves included with appropriate caution to prevent radioactive fluid backup?		
	Resolution:		
	Response:		
6.	Are catch pans, floor and equipment drains, and drip pans or curbing installed under valves that have a significant potential for leakage of radioactive liquids?		
	Resolution:		
	Response:		
7.	Are valves carrying primary coolant separated from associated equipment and components operated and maintained from the floor or a platform?		
	Resolution:		
	Response:		
8.	Are valves located in low-dose areas?		
	Resolution:		
	Response:		

9.	Do highly radioactive valves that are manually-operated have remote operating reach rods and/or are located in shielded cubicle or shielded valve galleries?		
	Resolution:		
	Response:		
10.	Are any modifications required that can be performed in a low-dose-rate area prior to installation (e.g., removal and plugging of gland seal leakoff lines)?		
	Resolution:		
	Response:		
11.	Are valves located so as to be easily operated and maintained from the floor or a platform?		
	Resolution:		
	Response:		
12.	Is quick access to packings provided?		
	Resolution:		
	Response:		
13.	Can the valve operator be quickly removed?		
	Resolution:		
	Response:		
14.	Are pressure relief or isolation valves provided with flanged connections to facilitate testing?		
	Resolution:		
	Response:		

15.	Are rigging and lifting points provided for heavy valve removal?		
	Resolution:		
	Response:		
16.	Has future decommissioning been considered (e.g., isolation valves for fluid systems)?		
	Resolution:		
	Response:		

XIII. ACCESS CONTROL CHECKLIST

		YES	NO
1.	Have frequently used pathways been located in low-dose rate and noncontaminated areas?		
	Resolution:		
	Response:		
2.	Are routes laid out so nonradioactive material does not have to pass through radiological areas and vice versa?		
	Resolution:		
	Response:		
3.	Are traffic routes such that individuals do not have to pass through radiological areas when traveling between two clean or general access areas?		
	Resolution:		
	Response:		

4.	Is the path for emergency personnel planned and clearly delineated?		
	Resolution:		
	Response:		
5.	Have frequently used pathways been located in low-dose rate and noncontaminated areas?		
	Resolution:		
	Response:		
6.	Is entry prohibited to areas where conditions are an immediate hazard to human life?		
	Resolution:		
	Response:		
7.	Is there a control device to prevent entry to areas when high radiation levels exist or upon entry causes the radiation level to be reduced below that level defining a high radiation area?		
	Resolution:		
	Response:		
8.	Is access prohibited to very high radiation areas?		
	Resolution:		
	Response:		

9.	Are there physical barriers to prevent the entry of unauthorized individuals into areas with significant concentrations of airborne radioactive materials?		
	Resolution:		
	Response:		
10.	Are panic exit bars provided on insides of locked doors?		
	Resolution:		
	Response:		
11.	Is the number of personnel access control points minimized?		
	Resolution:		
	Response:		
12.	Are personnel access control points adequate in size and associated equipment (e.g., personnel monitoring, card readers)?		
	Resolution:		
	Response:		
13.	Are temporary access control points available where it is anticipated they will be needed?		
	Resolution:		
	Response:		
14.	Is there adequate space (including maintenance and inspection), support, electrical hookups for personnel contamination monitors?		
	Resolution:		
	Response:		

15.	Are supports located so as not to interfere with inspections, maintenance and removal of equipment?		
	Resolution:		
	Response:		
16.	Are permanent platforms, rigging devices, etc., for easy access to components in hard-to-reach places?		
	Resolution:		
	Response:		
17.	Are sequential areas (e.g., general access to controlled to radiological) utilized?		
	Resolution:		
	Response:		

XIV. CONTAMINATION CONTROL DESIGN CHECKLIST

		YES	NO
1.	Have surfaces that are likely to become contaminated been painted or prepared so as to facilitate decontamination?		
	Resolution:		
	Response:		
2.	Have walls or curbing and floor or equipment drains been installed around equipment that has a high potential for leakage?		
	Resolution:		
	Response:		

3.	Are contaminated drains directed to the proper sump or tank?		
	Resolution:		
	Response:		
4.	Has space and support for glove bags and other containment devices been provided maintenance of heat exchangers, piping, valves, etc.?		
	Resolution:		
	Response:		
5.	Is hard piping to sumps used for tank overflows, valve stem leakage, etc.?		
	Resolution:		
	Response:		
6.	Are floors sloped to direct leakage to floor drains or sumps?		
	Resolution:		
	Response:		
7.	Are raised sleeves used for floor penetrations?		
	Resolution:		
	Response:		
8.	Are open gratings for stairs or platforms avoided in potentially contaminated areas?		
	Resolution:		
	Response:		

9.	Are stainless steel collection pans used?		
	Resolution:		
	Response:		
10.	Have services for decommissioning been provided (e.g., water, air, electricity)?		
	Resolution:		
	Response:		
11.	Are cleanout opening, taps, collection pans and means for flushing and draining systems been provided?		
	Resolution:		
	Response:		

XV. RADIOACTIVE WASTE CHECKLIST

		YES	NO
1.	Is there a designated area for storage of radioactive waste, with proper containment, shielding, monitoring, etc.?		
	Resolution:		
	Response:		
2.	Is the waste storage area large enough to accommodate twice the expected volume of waste?		
	Resolution:		
	Response:		

3.	Are distances minimized over which moderately and highly radioactive material is transported?		
	Resolution:		
	Response:		
4.	Are there monitoring systems to detect any leaks or spills where drainage or retention is unattended or is remote-controlled?		
	Resolution:		
	Response:		
5.	Are fire-suppression systems installed in all areas where combustible material may accumulate or be stored?		
	Resolution:		
	Response:		

XVI. SHIELDING, PENETRATIONS AND ROUTING CHECKLIST

		YES	NO
1.	Are labyrinth entrances used for High Radiation and Very High Radiation Areas?		
	Resolution:		
	Response:		
2.	Is shielding adequate for potential buildup of crud?		
	Resolution:		
	Response:		

3.	Have provisions been made for overlapping and stepping for removable shielding?		
	Resolution:		
	Response:		
4.	Have permanent hooks, latches, fasteners, and structural supports been added to secure temporary shielding?		
	Resolution:		
	Response:		
5.	Are penetrations minimized in number and size?		
	Resolution:		
	Response:		
6.	Are penetrations placed in the thinnest shield wall, near a corner, as high up as possible, and not in a line of sight with a source?		
	Resolution:		
	Response:		
7.	Have offset penetrations been considered?		
	Resolution:		
	Response:		
8.	Are primary containment penetrations sealed with respect to streaming, air-flow control, fire protection and flooding as applicable?		
	Resolution:		
	Response:		

9.	Are labyrinths or shadow shields used?		
	Resolution:		
	Response:		
10.	Have provisions been made so that no direct or reflected radiation escapes a shielded cubicle without passing through a suitable shield?		
	Resolution:		
	Response:		
11.	Are all serviced components (e.g., connections, junction boxes, panels) located in low-dose rate areas or at least on the low-dose side of the wall)?		
	Resolution:		
	Response:		
12.	Are run lengths of potentially contaminated pipes minimized?		
	Resolution:		
	Response:		
13.	Is there adequate clearance for maintenance, inspection, and insulation?		
	Resolution:		
	Response:		

XVII. SEPARATION, SEGREGATION, PLACEMENT AND ISOLATION OF EQUIPMENT CHECKLIST

		YES	NO
1.	Are shield walls used between components sharing the same cubicle?		
	Resolution:		
	Response:		
2.	Is passive equipment separated from active or frequently maintained equipment?		
	Resolution:		
	Response:		
3.	Is highly radioactive equipment segregated from moderately radioactive equipment, and both from clean equipment?		
	Resolution:		
	Response:		
4.	Are different systems segregated so that both systems do not have to be flushed, drained or decontaminated to reduce the dose when only one needs maintenance?		
	Resolution:		
	Response:		
5.	Are equipment areas laid out so that workers enter and progress from low-dose rate areas to moderate to high dose rate areas, and from active to passive equipment?		
	Resolution:		
	Response:		

6.	Are inspection, control and readout devices and panels located in low-dose rate areas?		
	Resolution:		
	Response:		
7.	Are services (e.g., demineralized water, electricity) located near entrances or at least in the lowest-dose rate areas?		
	Resolution:		
	Response:		
8.	Are isolation valves located as to minimize dead legs?		
	Resolution:		
	Response:		
9.	Are pipe runs minimized?		
	Resolution:		
	Response:		
10.	Are temporary interconnections used between systems of difference radioactivity potential?		
	Resolution:		
	Response:		
11.	Are redundancy and backup capabilities employed in system of high radioactivity content and safety systems?		
	Resolution:		
	Response:		

XVIII. ACCESSIBILITY, LAYDOWN AND STORAGE CHECKLIST

		YES	NO
1.	Have wide and large enough doorways and access areas been provided so that components can be easily removed for maintenance and inspection?		
	Resolution:		
	Response:		
2.	Has adequate laydown space been provided to accommodate equipment and component disassembly?		
	Resolution:		
	Response:		
3.	Are redundancy and backup capabilities employed in system of high radioactivity content and safety systems?		
	Resolution:		
	Response:		
4.	Is adequate working space provided around major components?		
	Resolution:		
	Response:		
5.	Are lifting devices provided for equipment?		
	Resolution:		
	Response:		

6.	Are permanent galleries or scaffolding provided where maintenance is frequent or prolonged?		
	Resolution:		
	Response:		
7.	Is there adequate access around welds?		
	Resolution:		
	Response:		
8.	Has the number of stops, hangers, supports and snubbers been minimized and are they orientated to maximize access space?		
	Resolution:		
	Response:		
9.	Have sectional or modular designs been considered (e.g., snap-on segments of insulation on heat-traced lines that require frequent maintenance)?		
	Resolution:		
	Response:		
10.	Are laydown spaces in low-dose rate areas?		
	Resolution:		
	Response:		
11.	Has storage been provided for hot tool and is it appropriate posted, locked, shielded and vented?		
	Resolution:		
	Response:		

12.	Has proper storage been provided for nonradioactive items?		
	Resolution:		
	Response:		

XIX. SNUBBERS, STRUT HANGERS, AND ANCHORING CHECKLIST

		YES	NO
1.	Are snubbers, struts, hanger and anchors designed and located so as to facilitate removal and replacements?		
	Resolution:		
	Response:		
2.	Have snubbers, struts, hangers, and anchors been located so as not to interfere with inspections and maintenance?		
	Resolution:		
	Response:		
3.	Have snubbers been replaced with struts or energy absorbers whenever possible?		
	Resolution:		
	Response:		
4.	Have snubbers, struts, hangers, and anchors been painted and tagged to facilitate location for repair and inspection?		
	Resolution:		
	Response:		

XX. HUMAN FACTORS CHECKLIST

		YES	NO
1.	Are signs, indicators, readouts, etc., clearly legible from a reasonable distance away?		
	Resolution:		
	Response:		
2.	Has nonstandard lettering been avoided?		
	Resolution:		
	Response:		
3.	Is lighting adequate?		
	Resolution:		
	Response:		
4.	Is background noise minimized around audible alarms?		
	Resolution:		
	Response:		
5.	Are audible alarms of sufficient decibels and placed to include all potentially occupied areas?		
	Resolution:		
	Response:		

6.	Has equipment that reduces number of workers (e.g., lifting devices, special tools) been considered?		
	Resolution:		
	Response:		
7.	Is there a provision for lifelines for tanks, pools or other areas with high dose rates or high airborne radioactivity?		
	Resolution:		
	Response:		
8.	Are permanent alignment marks on the equipment or floor?		
	Resolution:		
	Response:		
9.	Are tools, conduit, bolts, and pipes color coded?		
	Resolution:		
	Response:		
10.	Is insulation identified as to what is under it?		
	Resolution:		
	Response:		
11.	Are valve position, breaker settings, etc., clearly marked as to system lineup?		
	Resolution:		
	Response:		

12.	Are valves, valve operators, controls, etc., in a logical manner?		
	Resolution:		
	Response:		
13.	Has automation or use of interlocks and warning been considered for manual sequences of high consequence?		
	Resolution:		
	Response:		
14.	Are mockups and simulators available?		
	Resolution:		
	Response:		

XXI. OPERATION, MAINTENANCE AND INSPECTION CHECKLIST

		YES	NO
1.	Has adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc., been considered for operation of equipment?		
	Resolution:		
	Response:		
2.	Have remote operators or reach rods on high-dose rate valves been located outside contaminated areas?		
	Resolution:		
	Response:		

3.	Have instrument readouts been located in low-dose rate areas and away from contaminated areas whenever possible?		
	Resolution:		
	Response:		
4.	Can operations and surveillance be performed from outside a High Radiation Area through the use of remote readout devices, viewing ports, radiation detector ports or TV cameras?		
	Resolution:		
	Response:		
5.	Is access to equipment or instruments requiring frequent manual operation or surveillance via areas with the lowest possible dose rate?		
	Resolution:		
	Response:		
6.	Has adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc., been considered for maintenance of equipment?		
	Resolution:		
	Response:		
7.	Has the component or system been selected based on long-service life?		
	Resolution:		
	Response:		

8.	Are components requiring frequent maintenance (e.g., small pumps and valves) designed to permit prompt removal (e.g., flanged connections) to facilitate repairs in low-dose rate areas?		
	Resolution:		
	Response:		
9.	Have periodic maintenance items been eliminated whenever possible (e.g., O-rings, gaskets, packing protective coatings, lighting components)?		
	Resolution:		
	Response:		
10.	Have lubricating systems of self-lubricating units been considered?		
	Resolution:		
	Response:		
11.	Are provisions incorporated to allow rigging of the component? (E.g., pad eyes)?		
	Resolution:		
	Response:		
12.	Is access to equipment and components requiring frequent maintenance via areas with lowest dose rates practicable?		
	Resolution:		
	Response:		

13.	Does the valve maintenance procedure control stellite filings to reduce cobalt where neutron activation of the stellite possible?		
	Resolution:		
	Response:		
14.	Are components designed and oriented to minimize crud buildup?		
	Resolution:		
	Response:		
15.	Has adequate space around components, permanently installed platforms, lighting, ladders, outlets, etc., been considered for inspections?		
	Resolution:		
	Response:		
16.	Does insulation design allow for rapid removal and replacement (e.g., match marks, fiberglass blankets)?		
	Resolution:		
	Response:		
17.	Has equipment been laid out with consideration given to facilitating inspections required by Section XI of the ASME Code, Appendix J, Appendix R, and other inspection requirements of the ISI leak rate and fire protection program?		
	Resolution:		
	Response:		

18.	Are there visible tags and levels to identify equipment, snubbers, welds, penetrations, valves and other items requiring inspection?		
	Resolution:		
	Response:		
19.	Is access to equipment or components requiring frequent inspections via areas with lowest possible dose?		
	Resolution:		
	Response:		

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APPENDIX E - METHODS OF PERFORMING AN ALARA OPERATIONAL REVIEW

I. METHODS OF PERFORMING AN ALARA OPERATIONAL REVIEW

The following method is suggested as a practical way of accomplishing and documenting the review of a new or revised operation or job campaign, the "Operation" or the "Project."

A. Operations Team.

1. Consists of people who are providing input into the project, whether continuously or intermittently.

2. The Operations Team may include a member with radiological work experience, such as a radiological engineer, ALARA engineer, and a health physicist.

B. Contributor Group.

1. Consists of representatives of other groups who may not provide formal input to the operation, but whose comments and suggestions are considered relevant.

2. These may include maintenance, process, and research groups.

Members of the Operations Team and representative members of the Contributor Group may both participate in the ALARA Operational Review.

C. ALARA Review Coordinator.

There may also be an ALARA Review Coordinator appointed by the Radiological Control Manager or the Operations Manager. This individual may be an ALARA specialist, radiological engineer, or health physicist; for small or routine jobs, the individual may be a job supervisor trained in ALARA.

The ALARA Review Coordinator, with input from the Operations Manager, is responsible for seeing that the ALARA Review is performed, completed, and documented.

D. Information Gathering.

The beginning of the process is information gathering by the ALARA Coordinator.

1. The Coordinator should be knowledgeable about the functions, layout, equipment, and limiting factors associated with the operation, particularly:

a. Layout and location of the area;

b. Number and types of workers in each known or possible radiological area associated with each step of the operation;

c. Nature of each task workers are to do;

d. Time spent by each worker on each task;

e. Paths to and from the radiological area(s) and the transit time;

f. Physical features such as ladders, manholes, or hoods; and

g. Work-area-dose rates and wall thicknesses (in case shielding is needed).

2. Such information may come from systems descriptions, drawings, and other descriptive design documents, but could also come from walkdowns of the subject area, interviews with the manager of the operation and members of the Operations Team as appropriate, and discussions with vendors or contractors.

3. In particular, the Radiological Control Organization should be asked to provide historical dose and dose rate information, or to perform an appropriate radiological study of the area.

4. Based on this information, the ALARA Review Coordinator or designee (e.g., the local HP) should estimate doses and dose rates associated with the operation, taking credit for any engineered controls to be used.

5. The ALARA Review Coordinator should then describe the radiological features and implications in writing.

6. Small or Routine Jobs
   For small or routine jobs only, if a review such as this is done, the Radiological Control Organization may provide simple dose and dose rate information to the Coordinator, and the write-up of the job can be omitted if it is covered by routine job procedures, standard practice, or information on an RWP prepared for this job.

E. Preoperational Review (Planning Checklist).

1. The ALARA Review Coordinator sends or presents to the Operations Team and representative members of the Contributor Group the written information regarding the operation, proposed engineering and administrative controls, and the estimated doses.

2. The team and the representative Contributor Group members may use the Prejob (planning) section of the ALARA Operations Review Checklist as a tool to review and comment on this information.

3. The checklists they complete are sent to the Coordinator, who records the information in a report, as amended by the review, including all comments, their resolutions, and a listing of hold points.

   A hold point is a step in the operation where work is stopped for evaluation of progress of analysis of data or for radiological surveys and evaluations, pending a decision by named groups or individuals as to how or whether or not to proceed. "Named" means that their title or job classification is given in a procedure (e.g., "Do not proceed until HP has taken an air sample" or "If any individual dose exceeds 200 mrem at this point, do not proceed until the Facility Manager has approved a further dose increment").

4. The Coordinator combines the checklists from the various reviewers into a single-draft version of the ALARA Checklist, noting any discrepancies and resolutions of reviewer comments. (Note that only the Planning section is completed at this point.)

5. This checklist and other associated written information serves as documentation of the Prejob Review. As a report, it should be sent to:
   a. Members of the Operations Team,

   b. Members of the Contributor Group,

   c. Radiological Control section (including the area/facility safety representative if not on the Operations Team),

d. ALARA Program group, and

e. Other interested parties.

6. In the case of required ALARA reviews (e.g., by procedure), this can be written up as an ALARA plan for the operation. (For small or routine jobs, of course, no plan is required.)

7. Further revisions can be made to the Checklist write-up as necessary.

8. The Report eventually should be attached to the official copy of the RWP for future reference.

II. PREJOB REVIEWS

A. Preparation and Review of the Radiological Work Permit (RWP).

1. The RWP is prepared by the appropriate person(s) according to procedure, and necessary approvals are secured.

2. A further review of the RWP may be required in accordance with the RWP procedure.

3. After the RWP is written, the ALARA Review Coordinator, in consultation with the Operations Manager and the area/facility safety representative, establishes the dose and other applicable ALARA goals for the operation. These should be circulated to the same parties who received a copy of the Review Report and should eventually be attached to the official copy of the RWP.

4. The ALARA Review Report, the RWP, and the goals write-up together are referred to here as the "RWP Package."

B. Prejob Briefing.

1. The briefing is for supervisors, workers, an area/facility safety representative, and Radiological Control personnel.

2. It could range from a simple rundown of the radiological conditions to a more complete presentation that covers RWP requirements and the work procedure to be followed.

3. It could be a complete series of training sessions, including practice on mockups.

4. The radiological controls, which should be in place before the operation is started, should also be covered so that those people who are briefed will understand them before the operation is started.

5. Other operations conducted simultaneously, which could affect this operation, should also be described.

6. The ALARA Review Coordinator and the Operations Manager should determine the scope of the briefing based on advice from the Radiological Control Section or the ALARA Program group, or both, and information contained on the RWP Package.

C. Prejob Check (Start of Job Checklist).

1. This ensures that radiological controls are in place before an operation starts.

2. The Prejob Check should be performed by the Operations Manager or other designated person(s).

3. The work supervisor and area/facility safety representative in charge should also verify that radiological controls are in place.

4. The performance of these checks and verifications should be recorded in writing and signed by the individuals who performed them (there may be operating procedures for documenting this).

5. The Operations Manager should report to the ALARA Review Coordinator that the check has been done.

6. The ALARA Review Coordinator then completes the Start of Job section of the ALARA Operational Review Checklist.

III. OPERATIONAL REVIEWS

During the Operation (substitute site-specific titles as appropriate).

1. Tracking of dose and man-hours during the operation will normally be done by radiological control personnel.

2. The radiological control personnel may recommend or order that the work be stopped due to unexpected circumstances that may result in excessively high doses:

   a. Dose rates higher than anticipated.

   b. Airborne radioactivity levels higher than anticipated.

   c. Slow work completion rates.

   d. Unsafe working conditions.

3. The radiological control personnel may require simple alterations to the RWP if the circumstances are not likely to result in significant increases above the expected doses, or may request a revisitation of the ALARA review in view of the actual situation.

4. The scope of such a review should be decided by the Radiological Control Manager, the Operation Manager, and the ALARA Program Manager.

5. Facility operational management should cooperate in this review, whatever its scope.

IV. POST OPERATIONAL REVIEW

Substitute site-specific information as applicable.

1. Finally, when complete, the operation should be reviewed against the RWP Package by management, the Radiological Control personnel, and the ALARA program group.

2. The last section of the ALARA Operational Review Checklist (Postjob Review) should be filled out by the Operation Manager, the area/facility safety representative, and other parties, as appropriate.

3. These should be collated by the ALARA Review Coordinator into a final version of this section that should be circulated for final review and comment to appropriate parties, including the area/facility safety representative.

4. The ALARA Review Coordinator then produces the final version of the Postjob Review section of the ALARA Operational Review Checklist, adds it to the other sections, and sends it to appropriate parties. It is attached to the RWP to form the RWP Package or Work Package of record. Copies are retained as part of the required documentation.

5. Note that a formal job review even beyond the scope of this one may be procedurally required for some jobs.

6. If any ALARA goals, administrative levels, or regulatory limits were exceeded, the Radiological Control Organization and ALARA Review Coordinator should be informed, even if they were not involved up to this point (e.g., on a small job). The following should then be determined by the Operation Manager, area/facility safety representative, and ALARA Review Coordinator in consultation with these groups:

    a. Which ALARA goals were exceeded and why.

    b. Which administrative limits were exceeded and why.

    c. Which regulatory limits were exceeded and why.

    d. The effectiveness of dose reduction measures employed.

    e. Recommendations for future performances of this or similar operations.

7. The ALARA Review Coordinator should pool the findings in a memorandum or report to be presented to the Operation Division management, the appropriate committees, and other interested parties.

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APPENDIX F - COST-BENEFIT ANALYSIS

I. COST-BENEFIT ANALYSIS

Cost-Benefit Analysis (CBA) involves estimating the costs and benefits associated with a design change or modification to choose among alternatives or to select the optional value of a parameter. These costs and benefits must be estimated over the life of the new measure, feature, or practice. In addition, if adjustment is needed to correct for inflation, the techniques of engineering economics, such as the use of future value adjustment and annualization, can be used.

II. COST-BENEFIT ANALYSIS METHODOLOGY (CBA WORKSHEET)

A. (Dollar) Value of a Person-Rem.

In a CBA, all of the items to be considered must be expressed in the same units, usually dollars. Thus, to convert doses in a CBA to dollars, we must have a conversion factor. Such a conversion factor is called the (dollar) value of a person-rem. There may be actually several different values for different purposes. DOE has specified that this value(s) is to be set on a site-by-site basis; at (your site), this value(s) is $_____ per person-rem.

For comparison, note that NUREG-1530 states that the NRC now uses a value of $2,000 per person-rem, makes future value adjustments, and restricts the basis of this figure to health effects only.

B. Formal Methodology.

The point of optimization is to maximize the net benefit of an activity or design or of a feature of an activity or design. Thus, we have the following general equation:

$$B = V - P - X - Y$$

where B is the net benefit, V is the gross benefit, P is the costs of production not including radiation protection costs, X is the radiation protection costs, and Y is the dose cost. As can be seen, we can maximize B by maximizing V and minimizing P, X, and Y.

In practice, it is sometimes difficult to place a value on benefits and costs; for example, what is the value of a research activity that does not produce a marketable “product” but does produce useful information? For this reason, we try to look at only those components of B (i.e., V, P, X, and Y) that change and compare those. For example, if the only question is “one foot or two” of shielding and we can rule out effects on efficiency of operation, pipe routing, etc., as

insignificant, then we could look at only X and Y. This is true because with more shielding the cost goes up but the dose goes down, and vice versa. In this case, V and P would not depend on the value of the thickness, and we could write

$$dB/dt = d/dt\ (V - P - X - Y) = -\ d/dt\ (X+Y)$$

We can set this equal to zero so as to solve for the value of t that makes B a maximum and the sum of X + Y a minimum. Note that neither X nor Y is necessarily a minimum, but rather the sum must be a minimum. This approach works where X and Y (and possibly V and P as well) are functions of a continuous variable.

If we are comparing separate alternatives, we can again start from the B equation. For two alternatives, we have

$$B_1 = V_1 - P_1 - X_1 - Y_1$$

$$B_2 = V_2 - P_2 - X_2 - Y_2$$

For $B_2 \geq B_1$, we must have $(V_2 - P_2 - X_2 - Y_2) \geq (V_1 - P_1 - X_1 - Y_1)$, or

$$(V_2 - V_1) \geq (P_2 + X_2 + Y_2) - (P_1 + X_1 + Y_1)$$

That is, the net benefits of choosing Alternative 2 over Alternative 1 must exceed the net costs.

Note that where V and P are essentially the same in the two alternatives, this boils down to a shorter cost expression:

$$X_1 + Y_1 \geq X_2 + Y_2$$

Finally, note that if there is one new feature to be considered, we really have two alternatives: adopting the new feature or measure and not adopting the new feature (i.e., keeping the status quo). However, given a value of a man-rem, one can look at the “marginal” value of the alternative as follows. First,

$$B_1 - (V_1 - P_1 - X_1) = Y_1$$

$$B_2 - (V_2 - P_2 - X_2) = Y_2$$

Then,

$$B_2 - (V_2 - P_2 - X_2) - \{B_1 - (V_1 - P_1 - X_1)\} = Y_2 - Y_1$$

We see that the expression to the left of the equals sign boils down to the net savings or net costs, depending on whether the value is positive or negative. Similarly, the expression on the right is the net dose savings or net dose cost. Let us call the expressions the net cost and the net dose cost, with the understanding that these might actually be savings if the value is negative. We could proceed directly to this point by writing this ratio:

$$\Delta \text{ Costs}/\Delta \text{ Dose} = ?$$

If the ratio is positive, then the cheaper option also has the lowest dose. If the ratio is negative and its absolute value exceeds the site's ALARA criteria (in units of dollar/man-rem), then the measure is not cost-effective and should be not adopted. If the value is less, then it is cost-effective to adopt it. Many people prefer this "ratio of differences" method to the X + Y comparison method, but the former does not always give unique results and can be more difficult to interpret if there are more than two options or if optimization is to be done on a continuous variable.

C. Implementation of the Methodology.

There are four main steps in performing a CBA, as given below.

1. Describe each feature or measure, including the status quo where applicable. This should include the radiological implications of its adoption.

2. Estimate or calculate the applicable costs, benefits, and doses for each feature or measure. If any dose exceeds a regulatory limit or a contract provision, or there is any other such absolute barrier, then the feature or measure can be ruled out at once and the analysis need not be completed.

3. Determine the net benefit or a shorter cost expression of each feature or measure and then compare them. Or, where applicable, form the cost-dose difference ratio and compare it to the value of a person-rem.

4. Where the results are close or where there are uncertainties, perform a subjective factors analysis or a sensitivity analysis or both.

D. Description of a Feature, Measure, or Practice.

In describing a feature, measure, or practice, only information that has a bearing on the analysis should be provided. This would include the area or facility at which or for which the feature, measure, or practice would be adopted; the effects on radiological protection, such as increased need for shielding, reduction of respirator use, etc.; the applicable lifetime or period of use of the feature, etc.; and known costs, doses, and dose rates associated with the adoption of the feature or measure. The same should be done for each alternative to the feature, etc., including the status quo.

Note that sometimes constraints will limit alternatives. For example, since a dose of greater than 5 rem to 1 person would exceed the (annual) regulatory limit, it would not be acceptable to consider that as an option.

E. Production of Costs and Doses.

Once the known costs and doses have been produced, then the unknown costs and doses can be estimated or calculated from other information. For example, the known capital cost now may have to be annualized to compare it to operating costs in other years. Or the doses may have to be estimated from projected stay times and dose rates.

F. Comparison of Results and Use of Subjective Factors Analysis.

Once all of the costs and doses have been produced, they can be combined appropriately to produce the net benefit, a shorter cost expression, or the cost-dose differences ratio for each feature or measure. The results should be compared among alternatives or with the value of a man-rem, as applicable. The alternative with the highest net benefit or lowest cost expression should be chosen or, where the cost-dose difference ratio is used, features or measures with a ratio less than the cost of a person-rem may be chosen.

Where the results are close or where an analysis of more subjective factors is desirable, a sensitivity analysis might be performed in which the most important or most uncertain cost(s) or dose(s) is varied slightly to see how much difference variability or uncertainty makes. In addition or instead, a subjective factors analysis may be done. This is a ranking of the feature or alternative according to factors that are difficult to quantify but which are nevertheless important, such as schedule flexibility, reduction of the potential for a reportable occurrence, and good public relations.

G. Example.

Workers were doing an important job in a hot but uncontaminated area. A nearby valve suddenly started leaking radioactive water. This produced airborne radioactivity, so now the workers should probably wear respirators in the area while completing the hot job. Or should they? The leak has stabilized at a low but steady rate, and since it is an essential system, the valve system can't be turned off.

Consider an example with the following paramters:

Without the respirators, the job would take 2 workers 2 more hours to complete, with a resulting external dose of 100 mrem and 20 mrem internal (CEDE) to each.

With respirators, the time and the external dose for the job would also increase by 50 percent. Assume there would be no internal exposure.

The cost of an hour for a worker or HP is $75, and the cost of a person-rem is $2,000.

Here, doing the job right now is not presented as an option, but as a must. This may be because the job is the principal function of the facility, or the job may be required for safety or another important reason. So we start this example by assuming that we must do the job and that we are then trying to make the optimal choice regarding ways of doing the job. We are not given any information regarding contributions to P or V, so we will simply find the value of U = X + Y.

Option 1: Without Respirators

Without respirators, the cost of the job is calculated by

X_1 = (2 workers) (2 hrs) ($75 hr) = $300

The dose cost is

Y_1 = (2 workers)(0.100 rem+0.020 rem)($2000/person-rem)=$480

Thus, the sum is

$U_1 = X_1 + Y_1$ = $780

Option 2: With Respirators

With respirators, the cost of the job is

X_2 = (2 workers) (2 hrs * 1.5) ($75/hr) = $450

The dose cost is

Y_2 = (2 workers) (0.100 rem * 1.5) ($2000/person-rem) = $600

Thus, the sum is

$U_2 = X_2 + Y_2$ = $450 + $600 = $1050

Since U_1 gives the minimum value of U (i.e., the lowest total cost), this is the option that should be chosen. For this option, both the total dose and total cost is lower. Note that we ignored the cost of the respirators themselves (e.g., cleaning after use), but in a more complete analysis, this should be included.

Let's try this using the cost-dose difference ratio and the difference between (1) not using and (2) using respirators.

Δ Costs = X_2 - X_1 = \$450 - \$300 = \$150

Δ Dose = D_2 - D_1 = 0.300 rem - 0.240 rem = 0.060 rem

Δ Costs/Δ Dose = \$150/0.060 rem = \$2,500/(person-)rem

Since this is a greater than \$2,000/person-rem, the first option, not using respirators, is the one to choose. Since the ratio is positive, the lowest dose option and the lowest cost option are the same. There is no trade-off, and not using respirators is the correct choice to make.

If the above example had a higher internal dose component, the cost for not wearing a respirator would have been greater. For example, using option 1 (without respirators), an internal dose component of 100 mrem to each of the two workers would result in a total cost (U_1) of \$1100 if respirators were not used. This exceeds the cost of \$1050 when respirators are worn.

Keep in mind that the example presented here was simplified for instructional purposes. In practice, one must consider the following:

1) Studies have not consistently demonstrated that using a respirator will result in an increase in the time it takes to perform a task.

2) The radionuclide and chemical form involved, as well as the measures taken to ensure that workplace conditions do not deteriorate, must be factored into any controls implemented during the task.

3) Dose rates in a facility are variable, airborne radioactivity concentrations and worker practices.

4) There may be considerable worker opposition to accepting internal exposures, especially with respect to radionuclides with long biological half-lives, such as transuranics.

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